



EXPERIMENTAL GENERAL SCIENCE

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BY

WILLARD NELSON CLUTE

AUTHOR OF "LABORATORY BOTANY FOR THE HIGH SCHOOL," "OUR
FERNS IN THEIR HAUNTS," "AGRONOMY," ETC.

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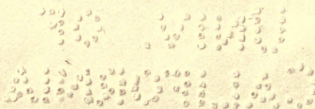
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GENERAL SCIENCE

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PREFACE

Much of the demand for courses in General Science in the schools is no doubt due to the ever increasing complexity of the more formal sciences there presented, but this is by no means the chief reason for the introduction of such a course. A large number of those who enter high school leave before completing the regular program of studies and thus fail to become acquainted with the special sciences, and still others elect courses which include only a minimum of these studies.

The principal claim of General Science to a place in the curriculum is that it will introduce such students, early in their school life, to some of the fundamental principles of science which are very essential to their success and happiness in life and which they would otherwise miss almost entirely.

That General Science is also needed as an introduction to the special sciences can scarcely be questioned. Enthusiastic teachers, engrossed in their own subjects, usually overestimate the amount of knowledge their pupils can bring to bear on the work in hand and unconsciously plan their courses on lines that are often beyond the ability of the student. The texts in science designed for use with high school classes are also frequently at fault, referring to such subjects as osmosis, change of state, capillarity, diffusion, the molecular structure of matter, and chemical elements and reactions as if they were customarily taught in the lower grades. In consequence, the study of science appears so forbidding to the beginner that none but the more venturesome elect it, and at a time when the world's interest in scientific things was never greater, we are confronted with the discouraging fact that in the schoolroom

interest in this most fascinating field of knowledge is steadily decreasing.

The aims of a text in General Science, therefore, appear to the author to be at least fourfold: to awaken in the student an interest in, and love for, science; to provide him early in his studies with a fund of useful information regarding scientific matters; to fit him for successfully negotiating such courses in the special sciences as he may later elect; and last, but by no means least, to initiate him into the laboratory method of solving new problems and thereby to develop his powers of observation, reasoning and judgment. An experimental course in the general principles underlying all science seems designed to most effectively accomplish these ends, provided the principles are adhered to and the teaching of the elementary parts of the special sciences avoided.

When the basic principles of the technical sciences are analyzed they are found to be almost entirely physical and chemical in their nature, since change in form, position, or composition is the rule in all earthly things. Astronomy, Geology, and Biology, with all their subsidiary divisions and ramifications, are merely studies in the application of these principles to special phases of nature. The theme of this book, therefore, is matter as it is affected by energy in its manifold forms. In order to make the contents of the course intelligible to the beginning student, no previous knowledge of the subject on his part is assumed, and the experiments and references are concerned with things with which he is already familiar or can examine for himself without special effort. In selecting these, however, the whole field of science has been laid under tribute but with no attempt to classify the matter into the usual formal divisions; indeed, the effort has been to avoid this. At the same time, the work forms a connected whole by the adoption of a related sequence which develops naturally and which is further knit together by numerous cross-references. The

practical exercises that follow each chapter touch upon phases of the subject not mentioned in the text and are therefore an integral part of the work and not a mere review of the text. If the student is encouraged to work out these exercises for himself, it will be found to advance his knowledge much more satisfactorily than mere recitations about them.

In arranging the chapters dealing with human physiology to follow those concerned with the more fundamental principles of all science, it has been possible to considerably reduce the matter devoted to this subject without omitting anything essential, since a large part of the usual high school course in physiology is taken up with discussions of the physics and chemistry of the bodily processes. If, however, it seems desirable to have physiology precede the more general matter, the student should be required to study carefully the other sections of the book in which the laws underlying physiological processes are treated at greater length.

The matter in this book has been used by the author with his classes in a large city high school for several years, and the practicability of the course, and especially of the experiments, has been tested under a variety of circumstances. In preparing the work for publication the author has had the advice and assistance of several of his fellow-teachers to whom he takes this opportunity of acknowledging his grateful appreciation. That he has not always followed the advice so kindly and cheerfully given will account for any errors that may be found in the text.

WILLARD N. CLUTE.

JOLIET, ILLINOIS.

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WILLIAM N. KINGSLEY
 NEW YORK, N. Y.
 1900

TO THE TEACHER

This book is so arranged that it may be used exclusively for recitations, but it is the sincere hope of the author that it may not be so used. In no subject are formal recitations less needed than in General Science. All the pupil needs is to be helped over the few hard places which happen to prove too difficult for his unaided efforts. In this way may be developed the initiative, ingenuity, and originality which every pupil possesses in greater or less degree. The experiments suggested are such as may be performed with inexpensive apparatus and materials and have been selected with a view of stimulating, as far as may be, the student's interest in science. Except in the very few instances in which the nature of the work or the materials makes it expedient for the teacher to perform the experiment, it will doubtless be found desirable to require each student, or small group of students, to do the work for themselves. In general, no amount of observing the work of others can take the place of individual effort.

The ideal way of handling the subject, and one whose worth has been proved by several years of practice, is to use the text as so much explanatory matter to be drawn upon in solving the problems presented in the practical exercises. By allowing each pupil to work for himself, the brighter students are not held back by those who are slower, nor are the latter swept off their feet in trying to keep up with the class. Pupils who have been out of school through sickness or otherwise, find upon returning to such a class that they are at no disadvantage except that they are somewhat less advanced in the subject and, if diligent, may soon overtake many of those who have not been absent. Moreover, much of the work may be performed at home if desired. If the extent of the course be

determined in advance, with the amount of credit to be given for its satisfactory completion, most pupils need no further stimulus to study.

The practicability of the experiments outlined has been demonstrated repeatedly by classes of beginning high school pupils working for themselves in an ordinary school-room equipped only with water and gas. A shelf should be provided for the few articles of glassware, reagents and other chemicals needed, and each student should be required to return each article to its place after use. The questions have been numbered to facilitate reference to them and the work may thus be abridged or expanded at any point. Throughout the course, the best results will be secured if the student is encouraged to investigate each subject further by consulting dictionaries, encyclopedias, and other text-books, and by discussing the questions with classmates, parents, and teachers.

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EXPERIMENTAL GENERAL SCIENCE

CHAPTER I

THE RELATIONSHIPS OF GENERAL SCIENCE

1. Scope.—When one begins a new study he is at once interested in discovering what ground it is proposed to cover, and what methods are to be used in covering it. At the outset, then, it may be said that General Science, as interpreted in this book, is concerned with the general principles underlying all manifestations of natural phenomena, together with a study of the methods which man has devised for taking advantage of these phenomena, and turning them to his own account. So far as we know, none of the lower animals feel an interest in the laws of nature. Man alone is disposed to seek the causes of things and to add to his store of knowledge for the sheer love of learning.

2. Scientific Methods.—The word Science, itself, comes from the Latin, *scientia*, meaning to know. It is, in fact, exact knowledge as opposed to speculative, second-hand, and hearsay information which may, or may not, be true. The body of scientific knowledge which we now possess has been established on a firm basis of fact by multitudes of carefully performed and scrupulously exact experiments. Many of these have been performed time and again by different observers in order to set at rest any reasonable doubt, or to approach more nearly to the truth. It is, of course, quite possible to gain a considerable amount of scientific knowledge through the reading of books, but such methods only give us information

regarding things already known. If we are to extend the boundaries of our knowledge, we must strike out along original lines, and study things themselves, using such knowledge as we already possess to aid us in the work. The laboratory method, therefore, is highly regarded by scientists, and may well be the method of approach by even the beginning student. What one finds out for himself by observation and experiment is understood better and remembered longer than information gained in any other way. Besides, one cannot really be said to know until he has seen and experimented for himself.

3. Special Sciences.—A single scientific principle, such as the fact that bodies expand on heating and contract on cooling, or that the air has weight, has hundreds of applications in industry and in the arts. When such principles are considered in their relations to a single phase of nature, they may give rise to special sciences. Among the special sciences are *astronomy*, which treats of the stars and other heavenly bodies; *geology*, *physiography* and *geography*, which are concerned with the structure and configuration of the earth; *chemistry*, which deals with the composition of all things and the changes which they undergo; *physics*, which treats specifically of the changes in form, position, and temperature of different substances; and *biology*, which is concerned with life and its manifestations. The latter is usually divided into *zoology*, which treats of animals, and *botany*, which deals with plants. *Physiology* is concerned with the functions, or life processes, of plants and animals. Arising from these are many other sciences, such as *medicine*, *pharmacy*, *agriculture* and *engineering*. When a science is studied with the object of enlarging the boundaries of our knowledge, it is usually called *pure science*; when it is studied in its practical or useful aspects, it is called *applied science*. These are not, however, distinct divisions. The discoveries of workers in the field of pure science are often of the highest value in practical affairs, while were it not for the

practical man, the scientist would lack many of his greatest conveniences.

4. Growth of Science.—The knowledge of scientific things was the latest department of the human understanding to be developed. Long before scientific methods came to be, art, music, literature, history, mathematics, and many other such subjects of study flourished. "The scientific attitude of mind" was rare in the days before the tools with which the scientist now works were invented. When the microscope, the telescope, the spectroscope and many other instruments of precision appeared, scientists made rapid progress. In the early days, too, ignorance and superstition conspired to retard scientific progress, and even sincere and inquiring minds found that the secrets of nature were discovered with difficulty. In these modern days, however, the conditions are changed, and every facility is offered the scientist in pursuing his investigations. The result is a wonderful development of all phases of science, but wonderful as the advance has been, it is probably not to be compared with what the future has in store for us. A general knowledge of scientific things, therefore, has become almost a necessity.

5. Practical Value.—The practical value of scientific discoveries lies in the power it gives us over the forces of nature, to the end that our lives may be made easier, happier, and richer. Few, if any, of our modern conveniences, not to speak of luxuries, would be possible without the scientist. Automobiles, telephones, aeroplanes, wireless telegraphy, submarines, thermos bottles, electric lights, steam engines, explosives, and a host of other things will come to mind in this connection. The structure or operation of these is often a matter of special study, but one does not need to be a machinist, a chemist, or a physicist to understand the principles on which they work. Moreover, life means more to those who understand why it rains, why it snows, why summer is hot and winter cold, why

warm air rises, why dew forms, why grass is green, and the sky blue. To solve such problems by the study of nature's laws, and in the solving to train the mind for the solution of other problems that may come up in later life, is the province of general science.

CHAPTER II

THE UNIVERSE

6. Extent.—Looking up at the sky, especially on a fine night in summer, one sees, in addition to the many brilliant points which we call stars, a broad, faint band of light extending across the heavens like an arch. This is known as the “milky way.” When it is examined with a telescope, it is found to consist of a great many bodies like our own sun, though most of them are so far away that they cannot be distinguished by the unaided eye. There are possibly a hundred million of these suns grouped in the form of a great hoop or girdle. The reason why we do not see this great assemblage of stars or suns as a circle is because our own sun is located within it and well toward the center. We can see only a section of it at one time, no matter from what part of the earth we view it, but if the earth were moved away and we could stand in its place, the circular form would be apparent. So far as we know, this great ring of suns, probably many of them with attendant worlds of their own scattered at immense and inconceivable distances from one another, make up the universe in which we have our being.

7. The Stars.—The points of light which we call stars are really suns like those of the milky way; in fact, they may be said to be parts of the milky way, the only difference being that those we call stars are near enough to us to appear as separate bodies and not as hazy points of light. Astronomers have discovered that many of the stars are larger than our own sun—the well-known “dog star,” Sirius, is more than twenty-five thousand times larger—and appear only as mere points of light because of their great distances from us. Our own sun,

which seems so brilliant, is probably only an insignificant member of the universe, and if viewed from the nearest star, would seem like a mere dot in the sky, if it could be distinguished at all. The difference in brightness which exists among the stars affords one convenient means of distinguishing them. The brightest are said to be stars of the first magnitude, the next brightest, of the second magnitude, and so on up to the sixteenth magnitude. There are less than twenty-five stars of the first magnitude. All the more conspicuous stars have names of their own, as befits their importance; others are given letters with reference to star groups. Some of these larger stars are well known because of their frequent mention in literature. Among these are Arcturus, Aldeboran, Polaris, Lyra, Algol, Rigel, Capella and Vega.

8. Light of the Stars.—All the visible stars are hot bodies like our sun, and shine by their own light. There is some difference in the quality of the light, as may easily be seen by comparing the brighter stars. Some have a bluish-white light, while others incline to a reddish hue. There is reason for believing that this difference in color indicates a difference in temperature, and that the blue stars are much hotter than the others. There are also large numbers of suns or stars that seem to have cooled off so much that they no longer give light, and it is possible that these dark stars greatly outnumber the bright ones. Our own sun, like the others, is believed to be cooling off, and in time may cease to send us light and heat. This event is so far distant, however, that millions of years must elapse before it occurs. The light that comes to us from the stars moves at the rate of about 186,000 miles a second, but even at that speed, the time required for the light of some stars to reach us must be measured in hundreds or thousands of years. The Pole Star (Polaris) is one of our nearest neighbors in space, but it requires forty-five years for a ray of light to travel from it to us.

9. Constellations.—From the earliest times the stars have been favorite objects of speculation and study, and much was known about them even before the invention of the telescope and spectroscope made more intimate study possible. Long before the dawn of history, man had looked up at the evening sky and fancying the stars grouped in forms resembling earthly objects, had given the names of these objects to the groups. Such groups are known as *Constellations*. Among the more striking of these are the Great Bear, the Scorpion, the Northern Crown, the Southern Cross, the Pleiades, Sagittarius, Orion, Boötes, and Pegasus. Others may be easily distinguished on a clear night. The seven principal stars in the constellation of the Great Bear are known to nearly every one as the “Big Dipper.” The constellations are not really related groups of stars, although they appear so when viewed from the earth. All are moving in various directions through the heavens, and in time, although it may be millions of years hence, they will have different positions from those they now occupy.

10. Motion of the Constellations.—Observers of the heavens soon discover that the constellations, though retaining their places with respect to one another, do not have a definite position in the sky but steadily drift westward. This apparent motion is due to the revolution of the earth about the sun which thus causes us to view them from a different position in space each time we see them. They are, however, to be found in the same positions on the same dates each year because at the end of a year we have returned to the exact spot from which we viewed them a year earlier. The drifting westward or, rather, our change in position with regard to the constellations, causes one after another to disappear in the west while new ones appear in the east. For a part of each year, therefore, some of the constellations are invisible. Among those most conspicuous in our summer skies are Boötes, the North-

ern Crown, Sagittarius, Pegasus, and the Scorpion. In winter Orion is easily the most conspicuous. Owing to the rotation of the earth on its axis, most of the constellations appear to rise and set nightly. A few in the north, including the Great Bear, are so situated with respect to the earth that they never set but appear to circle endlessly about the pole star. This is because the earth's axis points toward the part of the heavens in which the pole star—the so-called north star—is located. For the same reason, there are other constellations that never rise for us, being below our southern horizon and hidden from us by the great bulk of the earth. Since our north pole points in the direction of the north or pole star, an observer at the pole would find the star overhead, and at the equator it would be on the horizon. The number of degrees the pole star is above the horizon in any given locality is the number of degrees the place is north of the equator, that is, it is the latitude of the place.

11. The Solar System.—Our sun with its attendant bodies, called planets, comprises the solar system. There are eight planets which, named in their order from the sun outward through space, are Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. As seen with the unaided eye, most of the planets appear as rather bright stars. Owing to the fact that they are so near us, their motion is very noticeable, and consequently they do not have definite places in the sky, but change their courses with the seasons. The ancients called such stars "planets" (which means "wanderers") to distinguish them from the "fixed" stars which seemed to them to be fixed in their places. Often the planets are especially noticeable, as when they appear in the evening sky shortly after sunset.

12. The Sun.—Although so insignificant compared with the other stars, our sun is still a body of vast dimensions. It is, in fact, about a million times larger than the earth and seven

hundred and forty times the bulk of all the planets combined. If the sun were represented by a globe twenty-five feet in diameter, the earth, on the same scale, would be a ball three inches in diameter. The sun is the source of light and heat for the planets, and the center about which they all revolve, being held in their courses by that mysterious force called gravity, which acts between all the heavenly bodies with a strength that is in proportion to their masses and their distances from one another.

13. The Planets.—Of the eight planets, the four outermost are larger than the earth. Jupiter, the giant planet, is about fourteen hundred times as large. The average distance from the earth to the sun is 92,800,000 miles. Neptune, the farthest planet, is thirty times as far, or nearly three billion miles. All the planets move about the sun from east to west in periods in proportion to their distance from it. Mercury makes a complete revolution in eighty-eight days, while Neptune requires one hundred and sixty-five years for the journey. The two planets nearest the sun have no moons and the earth has only one, but Mars has two, Jupiter nine, Saturn ten, Uranus four, and Neptune one. In addition, Saturn has a broad luminous belt of rings about its equator.

14. The Moon.—The earth's only satellite, the moon, is a much smaller body which revolves about it just as the earth itself revolves about the sun. It is much nearer to us than the sun, being in fact, only two hundred and forty thousand miles away. It makes one revolution about the earth in twenty-nine days, and revolves on its own axis once during that time, in consequence of which, we only see one side of it. The configuration of the visible side, however, is as well known as similar areas on the earth. The moon shines by reflected sunlight, but the amount of moonlight we receive varies with the amount of the illuminated surface visible. When the sun, moon, and earth are in such a position that we

see the fully illuminated half of the moon, we call it *full moon*. When only part of the moon is visible it may appear as a crescent. The *new moon* always appears in the western sky shortly after sunset. To an observer on the moon, the earth would appear exactly like a larger and brighter moon. The fact that the earth really does shine to the other planets may be realized when, as occasionally occurs, the whole moon is faintly outlined at the time of new moon. Since the bright crescent is the only part that reflects the sun's rays, the faint illumination of the rest of the surface must be due to earthshine. This appearance is frequently spoken of as the "old moon in the new moon's arms."

15. Eclipses.—An eclipse always occurs when a body comes between any of the heavenly bodies and their source of light. Eclipses of the moon, therefore, are caused by the earth coming between the moon and the sun. The moon passes into the earth's shadow and is totally or partially eclipsed. Eclipses of the sun are due to the passing of the earth through the moon's shadow; that is, the moon passes between us and the sun, cutting off the sun's light from us. To an observer on the sun, this would appear as an eclipse of the earth. The reason why we do not have eclipses of the moon more frequently is because its path about the earth is not in a plane parallel to the earth's orbit and does not dip into the earth's shadow on each revolution.

16. Shooting Stars and Comets.—On a clear night, we may often see what appears to be a star falling toward the earth. The stars, however, do not fall. What seems to be a falling star is really a small particle of matter which our earth has encountered in its travels through space, and which has become so hot from rubbing against our atmosphere that it shines. Such bodies are often called *shooting stars*, or *meteorites*. They usually consist of iron or stone. Great numbers of meteorites come into our atmosphere annually, but most of them burn up

before they reach the ground. A few heavier ones have fallen to the earth. Some of these weigh more than a ton each. Specimens may be seen in almost any large museum. *Comets* are probably aggregations of matter similar to that in meteorites and often in a gaseous form. Some comets have a regular orbit about the sun, and may come and go at different times. Others may appear but once and, traveling past the solar sys-

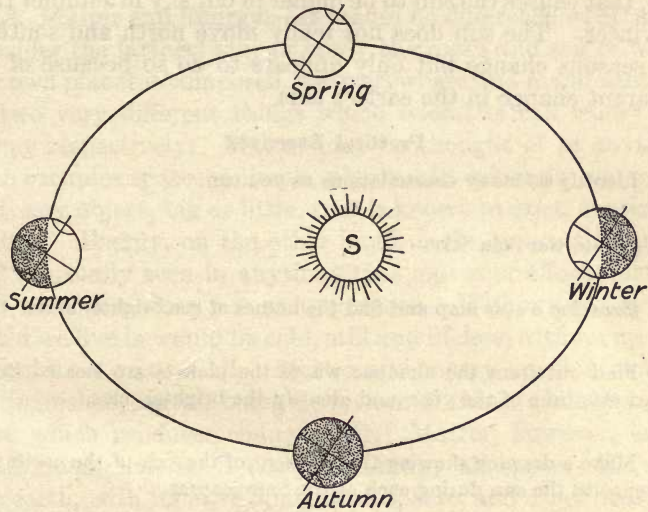


FIG. 1.—Position of the earth's axis with reference to the sun during the year.

tem, finally become too faint to be seen with the telescope, and may be lost among the distant suns.

17. Time on the Earth.—The various motions of the earth serve as convenient measures of time. Thus the time required for the earth to make one revolution about the sun is a *year*, while its rotation on its axis produces *day* and *night*. The *month* is partly an artificial measure of time, but it nearly corresponds to a revolution of the moon about the earth, this latter occurring in about 29 days. The movement of the earth

about the sun, in connection with the tilting of the earth's axis, causes the *seasons* (§152).¹ The axis is so directed in space that first one pole and then the other is brought nearer to the sun. When one pole is toward the sun, the parts of the earth near it have *summer* and the opposite region has *winter*. *Spring* and *autumn* are the seasons between, when neither pole is nearer the sun. It is the inclination of the earth's axis, also, that causes the sun to be higher in our sky in summer than in winter. The sun does not really move north and south as the seasons change but only appears to do so because of the apparent change in the earth's axis.

Practical Exercises

1. Identify as many constellations as you can.
2. Locate the Pole Star.
3. Examine a star map and find the names of the brighter stars.
4. Find out from the almanac where the planets are located in the sky at this time of the year, and identify the brighter ones.
5. Make a drawing showing the positions of the axis of the earth with reference to the sun during each of the four seasons.
6. Look for the "earthshine" at the next new moon.
7. The moon goes around the earth in a direction the reverse of the sun's apparent motion, that is, from west to east. Can you account for the fact that the moon usually rises nearly an hour later each evening?
8. How long is a day on the moon?

¹ The references are to other sections in this book where the subject under discussion is further mentioned. The student is urged to consult all such references as an aid to the proper understanding of the subject.

CHAPTER III

STRUCTURE OF MATTER

18. Matter and Energy.—It makes no difference whether we consider the farthest star or study the rocks and soil of which our own planet is composed, we everywhere find manifestations of two very different things which scientists call *matter* and *energy* respectively. Matter may be thought of as anything that occupies space—animals, plants, air, minerals, water—in fact, any object, big or little, that is known to exist, consists of matter. Energy, on the other hand, is the power to do work and is usually seen in anything that moves or affects matter, and of course does not occupy space. Without energy the world we live in would be cold, still and lifeless; without matter, it could not exist at all. Matter and energy are thus sharply distinguished, matter being a substantial thing, while energy is that which produces change in it. Matter, however, is not continuous; that is, it does not occupy all space. Between the earth, with its enveloping atmosphere, and other heavenly bodies are vast stretches in which, so far as we know, no matter of any kind exists. Space on the earth that does not contain matter is called a *vacuum*. The space in a thermometer-tube above the mercury is a nearly perfect vacuum.

19. The Molecular Theory.—All matter is regarded as being made up of very small particles, called molecules, which are far too small to be seen even with the highest powers of the microscope. Some idea of how small molecules really are may be gained from the fact that a thimbleful of gas at ordinary temperatures will contain more than 75,000,000,000,000,000-000 molecules. Although nobody has ever seen molecules, and

probably never will, scientists have devised means of weighing and otherwise measuring them, and thus have proved the truth of what has long been known as the *molecular theory of matter*.

The molecular theory enables us to understand how it is possible for matter to change its form. Water, for instance, may exist as a *solid* (ice), a *liquid* (water), or a *gas* (steam), and in each of these states, the same quantity has a different size. If matter were continuous and not composed of many small particles, it is difficult to see how it could expand and contract in this way. Various experiments may be performed to illustrate the molecular structure of matter; thus, if salt is slowly sifted into a test-tube of water, fine bubbles of air are seen to rise to the surface. These air bubbles are composed of molecules of air which were crowded out from between the molecules of water by the salt. Again, water at high pressure may be forced through sheets of solid steel or other metals, and carbon dioxide gas easily passes through red-hot iron. A single drop of soapy water contains so many molecules that when blown into a soap bubble more than a foot in diameter, there are enough to form a continuous film throughout.

20. States of Matter.—Water is not the only substance that may exist in three states—solid, liquid, and gaseous. Many other substances change in the same way when conditions are favorable. Each state has certain characteristics peculiar to it. Solids always have a shape of their own and resist with considerable force any effort to change it. When solids are changed to liquids, however, they invariably take the shape of any vessel in which they happen to be, with the upper, free, surface level. Gases have neither shape nor size (volume) of their own. They fill any space open to them, and push outward with equal force in all directions. For this reason, they cannot be kept in an open vessel like solids and liquids. If left uncovered, the molecules at once begin to fly away. If

the space containing the gas is made larger, the gas at once fills it, and if it is made smaller, the molecules are simply forced closer together. In some cases, if the gas is compressed enough, the substance may be made to assume the liquid form again. The fact that the free surface of a liquid is absolutely level is often taken advantage of in grading and building. A hose filled with water may be used. The water in one end of the hose will always be exactly level with that in the other (§98).

21. Some Properties of Matter.—There are a number of properties which we recognize at once as characteristic of matter. Among these are *weight*, *hardness* and *brittleness*. Other characteristics with which we may not be so familiar are *elasticity*, *tenacity*, *malleability* and *ductility*. *Elasticity* is the tendency of matter to return to its original shape and volume after being bent, compressed, stretched, or twisted. Rubber is a very elastic kind of matter, and air is another. Air, it is true, cannot be bent or twisted, but when enclosed in an air-chamber or automobile tire, it has almost perfect elasticity. *Tenacity* is the capability of a thing to resist being pulled apart. A steel wire has great tenacity. *Malleability* is the quality of withstanding being hammered out into sheets without cracking and *ductility* is the capacity of being drawn into wire. Copper is both malleable and ductile; limestone is neither. The metal platinum is so ductile that it may be drawn into a wire scarcely visible to the eye. Gold may be beaten out into sheets so thin that it would require 300,000 of them to make a pile an inch high. Not all of the characteristics mentioned are likely to belong to any one substance, or kind of matter, but all substances possess several of them. There are many other qualities that characterize different substances. Some, for instance, may be *crystalline*, or composed of crystals; others may be without definite form, or *amorphous*. Glass, pitch, paraffin and similar substances are

amorphous. Some are *transparent* and allow light to pass through them; others are *opaque* and stop the light. All kinds of matter are said to be *impenetrable* in that they take up a certain amount of space to the exclusion of everything else, and they are also *indestructible*—that is, they cannot be destroyed. It is true that we may appear to destroy matter, as when we burn a block of wood or explode gunpowder, but no matter is really destroyed. In the instances mentioned, matter has merely changed its composition and now exists as gas or ashes, or both.

22. Physical and Chemical Change.—The changes which occur in matter may affect either its form or its composition. When the change does not affect the *composition* of matter, as when iron is melted or water is turned to steam, it is called a *physical change*. The science that deals with such changes is called *physics*. When the composition of matter is changed, as when wood burns, iron rusts, or quicklime slacks, it is called a *chemical change*. Such changes are studied in *chemistry*. In physical changes the original substance may usually be recovered again by reversing the process by which it was changed. Thus, if ice be heated until it becomes water, it may be turned to ice again by withdrawing the heat. In chemical changes, one or more new substances are formed and the original substance is not usually to be obtained again by reversing the process. Wood once burned cannot be had as wood again until the plant has built it up once more from the gases and ashes into which it was turned by burning.

Practical Exercises

1. Why does one have difficulty in pouring a liquid into a bottle through a close-fitting funnel?
2. Dissolve a single crystal of potassium permanganate in a test-tube of water. What gives the color to the water?

3. How much water will a crystal of potassium permanganate color?
4. What does the foregoing teach as to the size and number of molecules in the substance used?
5. Select the substances in the following list that are elastic, those that are malleable, and those that are ductile; make a list of each: iron, rubber, clay, lead, glass, coal, ice, copper, wood, limestone.
6. Name the solids, liquids, and gases in the following list: sand, mercury, salt, soda, olive oil, steam, air, and vinegar.
7. Arrange the following in two lists, one of physical changes and the other of chemical changes: the souring of milk, the melting of ice, the rusting of iron, the rotting of wood, exploding gunpowder, photographing, breathing, evaporation.
8. Into a long narrow test-tube half full of water pour an equal amount of alcohol. Mark the exact height of the liquids, cork and shake well. How do you account for the difference in the height of the liquids which you can now observe?

CHAPTER IV

ENERGY

23. Movements of Matter.—Matter is seldom, if ever, in a complete state of rest. Suns and planets are ever in motion through the heavens, wind blows, smoke rises, water evaporates, rain falls, and grass grows. Even when the substance does not move as a whole, its molecules are in rapid motion. A rock or a piece of metal expands when heated and contracts when cooled, thus changing both its size and temperature. Matter, however, cannot move of itself. All the movements which the various forms of matter exhibit are due to the effects of energy upon them.

24. Heat and Molecular Motion.—All of the molecules of a substance, as we have already learned, are supposed to be in constant and rapid motion. The speed of a molecule of hydrogen gas at ordinary temperature is more than a mile a second. Oxygen molecules travel about one-fourth as fast, and the molecules of other substances have similar speeds. If the molecules of the air moved continuously in one direction, instead of vibrating back and forth, it would produce a breeze of more than fifteen miles a minute, a velocity sufficient to blow away everything in its path. While we cannot follow the molecules in their flight, we may, by proper experiments, see the results of such motion. If a small quantity of india-ink be mixed with water and viewed with a microscope, each particle is seen to be in rapid oscillation. Since these particles cannot move of themselves, their motion is regarded as being caused by the multitudes of molecules colliding with them. The motion of the molecules is caused by the heat they contain;

in fact, in this sense, it may be said that heat *is* motion, for by simply increasing the heat of a substance, its molecules may be made to move faster and farther apart, while withdrawing the heat reverses the action. The differences noted in the three states in which matter is capable of existing are largely due to the different amounts of heat they contain, for solids may be made liquid by adding heat, and liquids may be turned to gases by adding still more heat. Adding heat to a gas increases the speed of its molecules and causes them to move outward with greater force. It is these myriads of flying molecules, striking against whatever confines them, that produces the pressure noted in all gases when confined. In steam boilers, the pressure of the confined steam sometimes becomes so great that it causes disastrous explosions. When a gun is fired, it is the pressure of the gas generated that gives the speed to the bullet (§53). Gases and liquids are often called *fluids*. The molecules of fluids move easily and smoothly past one another, but in solids the motion is more restricted. All are in motion, however.

25. Forms of Energy.—Besides heat and the energy of motion already mentioned, there are three other forms of energy that are more or less familiar. These are light energy, electric energy and chemical energy. All forms of energy are closely related; in fact, are but different forms of the same thing, as is shown by their changing from one form to another, and by their producing changes in matter. Electricity, for instance, may be produced by chemical energy and used to give motion to cars, elevators and the like. The same force, properly treated, will light the cars, and if desired, heat them as well. Chemical energy is often liberated when two substances are united, and frequently appears in the form of heat. Water put on quicklime may release enough chemical energy to boil the water. Instances of this are often seen when plaster is being mixed. Sulphuric acid poured into water

also produces a large amount of heat. Burning gas jets and oil lamps are instances in which both light and heat result from chemical energy. In fact, all ordinary burning is due to the union of the gases of the air with a combustible substance. Since heat causes molecular motion, it is not surprising to find that motion may be turned to heat; even rubbing the hands together increases the heat in them. When a bullet strikes a target, the motion of the bullet ceases, but both the bullet and the target are heated. Brakes may be applied so

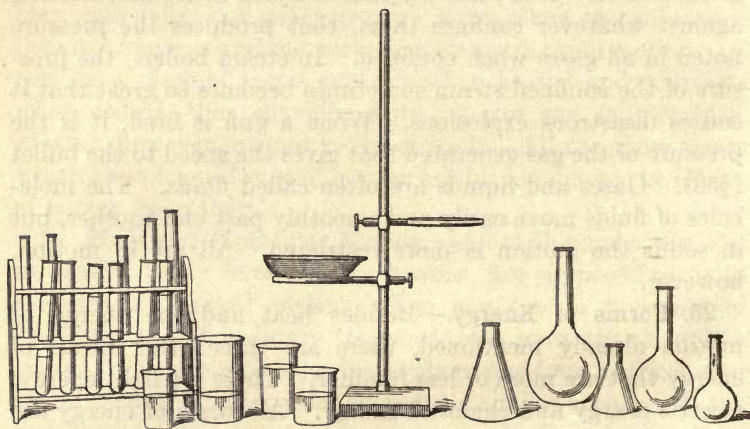


FIG. 2.—Test-tubes, beakers, flasks and stand used in making experiments.

closely to car wheels as to cause sparks to fly from them. In other days before matches were known, fire was made by striking flint a glancing blow with steel. The motion of the flint against the steel generated enough heat to make small particles of the flint red-hot. Even the air, which at first thought seems too light and thin to offer much resistance to bodies passing through it, may nevertheless produce much heat in this way as in the case of the so-called shooting stars, which, in their fall to the earth become so hot by merely rub-

bing against the air that they shine. From the fact that whenever one form of energy disappears another form appears in its place, we conclude that energy, like matter, cannot be destroyed.

26. Kinetic and Potential Energy.—Upon examination we find that all kinds of energy fall into one of two classes. When energy is actually doing work, as in water falling over a dam, or the uncoiling of a spring, we speak of it as *kinetic energy*. When it is capable of work, but not actually working, as is the water above the dam, or the coiled spring, it is called *potential energy*. Energy, as we have noted, may be changed from one form to another, and it may also be transferred from one body to another. In winding up a clock, we transfer some energy from our own body to the clock spring. If the clock is run by weights, we transfer energy when we lift them. The kinetic energy expended in this work becomes potential energy until the clock starts to run, and then it becomes kinetic energy again.

27. The Source of Energy.—The sun is the earth's one great source of energy. Engines have been constructed that derive their energy directly from the sun's rays, but generally we make use of the energy in sunlight after it has been transformed in various ways. Windmills, for instance, are turned by currents of air which owe their direction and force to the unequal distribution of heat over the earth's surface. Water-wheels secure their energy from falling water which has previously been evaporated by the sun's heat, blown over elevated regions, in the form of clouds, and condensed again as rain. Peat, coal, oil, and gas have been formed from the remains of plants and animals of past ages, which built up their tissues from energy derived from the sun's light and heat, just as they are being built up at present.

28. Heat and Light Compared.—Heat and light are closely related in that they come from the sun in the form of *radiant*

energy, which travels about 186,000 miles a second and takes some eight minutes to cross the more than 92,000,000 miles that separate us from the sun. Radiant energy moves forward in straight lines, but the waves of which it consists vibrate very rapidly back and forth across the direction of the rays. It is not until it comes into contact with some form of matter that radiant energy becomes heat or light. The principal difference between them appears to be that light rays are much more rapid than heat rays, and affect a different one of the senses. Light rays vibrate with inconceivable rapidity. The rays that give the sensation of red vibrate 392,000,000,000,000 times a second and those which give the sensation of violet vibrate 757,000,000,000,000 times a second. Some of the invisible rays which affect the photographer's plates and films vibrate twice as fast as the violet rays (§134). Both heat and light rays can be bent or reflected, very smooth surfaces, such as mirrors, being most effective in this respect. As *radiant energy*, heat rays readily pass through transparent substances, but when they strike opaque bodies some of the energy is absorbed as heat. When the heat is again turned to radiant energy of a longer wave length (§77), it does not then pass easily through even transparent bodies. It is due to this fact that greenhouses and hot-beds are sometimes called "traps to catch sunbeams." Most of the radiant energy readily passes in through the glass roof, but after being changed to the longer heat rays, finds escape difficult, and thus remains to warm the plants in the enclosure. The water vapor in the air acts in a similar way to keep the earth warm, allowing the radiant energy to pass through it, but preventing the passage of the long heat rays.

Practical Exercises

1. Why does the snow melt at the base of trees and other objects before it melts in open fields?

2. The air in the tires of bicycles left standing in the sun soon show increased pressure. Why?

3. Dough contains bubbles of carbon dioxide gas. How does the heat of the oven cause the bread to rise in baking?

4. Which is warmer, the water at the top of a water-fall or that below? Why?

5. At the temperature of absolute zero there is no heat in a substance. How would this affect the motion of the molecules?

6. When the hand is held in the sunlight coming through a window-pane, it feels warmer than the pane does. Why (§28)?

7. Why is the air cold at some distance from the earth when the heat energy from the sun passes through it?

8. How does hammering a piece of metal affect its temperature?

9. How does it affect the speed of its molecules?

10. What was the source of energy which caused the changes noted in the foregoing experiments?

11. Which do you infer would warm more quickly in the sunlight, a board, or the air near it?

12. Pick out the instances of kinetic and potential energy in the following list: a coal fire, driving a nail, a rock on a mountain side, a stick of dynamite, coasting down hill, a loaded gun.

CHAPTER V

COMPOSITION OF MATTER

29. Chemical Elements.—In studying the structure of matter, we have discovered that it is made up of exceedingly small particles called molecules, but we have yet to learn what molecules are made of. Chemists and physicists who have investigated this problem are of the opinion that molecules are composed of still smaller particles called *atoms*. There are, of course, as many different kinds of molecules as there are different kinds of matter, but atoms are less common; in fact, there are only about eighty different kinds. Since the molecules are built up of these atoms, the differences that they exhibit must be due to differences in the number and kinds of atoms of which they are composed. When a substance has only one kind of atom in its molecules, it is called a *chemical element*. Gold, copper, iron, and other metals, mercury, sulphur, carbon, and phosphorus are examples of chemical elements. According to our definition, there can be, of course, only as many different kinds of chemical elements as there are different kinds of atoms. Most substances, therefore, are composed of more than one kind of atom, and are called *chemical compounds*. Often a very slight difference in the structure of the molecule may make a great difference in the substance. For instance, such substances as sugar, vinegar, starch, wood, alcohol, fat, and oil are merely different combinations of the three chemical elements, carbon, hydrogen, and oxygen. About a hundred thousand different combinations of carbon with other elements are known.

30. Distribution of the Chemical Elements.—The different chemical elements are very unequally distributed in the earth's crust. Some, like radium, are extremely rare, and occur only in combination with other elements. Others are very common and occasionally occur in the pure or "native" state. Gold, silver, copper, and some of the other metals may be found native. The oxygen and nitrogen in the air are uncombined, but usually these elements are combined with others, and in the

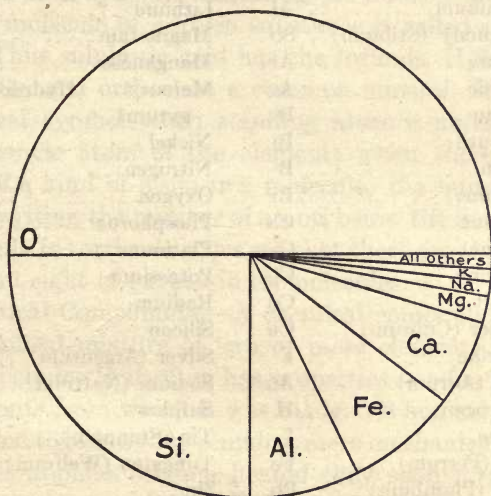


FIG. 3.—Proportion of various elements in the earth.

latter state may be found in vast deposits. About 95 per cent. of the earth is made up of the five elements, oxygen, silicon, aluminum, calcium, and iron. Oxygen is the most abundant of the elements and itself forms nearly one-half the earth. It forms one-fifth of the air, eight-ninths of the water, and enters into a great many combinations with other elements. Carbon is found in practically all organic substances; that is, in all substances formed by living things. Silicon is the essential

part of all sand, sandstone, and quartz rocks. Aluminum is present in clay, and calcium is a necessary component of all limestone rocks. Crystalline carbon forms the diamond, and crystalline aluminum with oxygen forms the ruby, emerald and sapphire. Corundum, or emery, is an impure form of the crystalline state of this compound. The more common chemical elements are given in the accompanying table:

Name	Symbol	Name	Symbol
Aluminum.....	Al	Lithium.....	Li
Antimony (Stibium)..	Sb	Magnesium.....	Mg
Argon.....	Ar	Manganese.....	Mn
Arsenic.....	As	Mercury (Hydrar- gyrum).....	Hg
Barium.....	Ba	Nickel.....	Ni
Bismuth.....	Bi	Nitrogen.....	N
Boron.....	B	Oxygen.....	O
Bromine.....	Br	Phosphorus.....	P
Calcium.....	Ca	Platinum.....	Pt
Carbon.....	C	Potassium.....	K
Chlorine.....	Cl	Radium.....	Ra
Cobalt.....	Co	Silicon.....	Si
Copper (Cuprum)....	Cu	Silver (Argentum)...	Ag
Fluorine.....	F	Sodium (Natrium)...	Na
Gold (Aurum).....	Au	Sulphur.....	S
Hydrogen.....	H	Tin (Stannum).....	Sn
Iodine.....	I	Tungsten (Wolfram).	W
Iron (Ferrum).....	Fe	Zinc.....	Zn
Lead (Plumbum)....	Pb		

31. Chemical Symbols and Formulas.—In order to facilitate his work and save time and space in writing, the chemist has an abbreviation for each chemical element, which he uses instead of the name. This is called a *chemical symbol*. The chemical symbol is usually the initial of the element, but in cases where more than one element have the same initial all but one have a single letter added. Thus C always stands for carbon, while the chemical symbol for calcium is Ca, for copper, Cu, and for chlorine, Cl. No chemical element has more than two let-

ters in its symbol, and the second letter is always a small letter. Co therefore, stands for cobalt, an element, but CO stands for carbon monoxide, a chemical compound of carbon and oxygen. A few elements, such as sodium (Na), silver (Ag), and potassium (K), have symbols which do not include their initials. In such cases, it will be found that the symbols were given to these substances when they were called by other names. The names have since been changed, but the symbols have not. A group of chemical symbols indicating the number and kind of atoms in a molecule of a given substance is called a *chemical formula*. Thus sulphuric acid has the formula H_2SO_4 , limestone, CaCO_3 , and orthoclase a common mineral, $\text{K Al Si}_3\text{O}_8$. The chemical symbol when standing alone is understood to indicate a single atom of the element; when there is more than one of a kind of atom in a molecule, the number is indicated by writing the number of atoms below the line. Thus, in the formula for orthoclase, we see that there are three atoms of silicon and eight of oxygen in its molecules. .

32. Chemical Compounds.—A chemical compound is not a mere mechanical mixture of two or more elements, but is a different substance that often has properties not found in any of the elements from which it was made. When sulphur and iron are mixed together they remain a mere mechanical mixture until heat is applied. When heated they soon form a new substance known as sulphide of iron. This has a different color from the substances composing it, and is not affected by a magnet, though the iron before it was combined was strongly attracted. It is not always possible, however, to tell in advance what sort of a substance will be formed by the union of two or more elements. The union of two gases does not necessarily produce a gaseous compound, nor does the union of two solids always produce a solid. Water, which is a liquid at ordinary temperatures, is composed of two gases, oxygen and hydrogen. When these gases are free and uncombined,

they cannot be made liquid except under great pressure and at an extremely low temperature. Table salt, the familiar white solid, consists of sodium, a silvery solid, and chlorine, a greenish and poisonous gas. Still more remarkable is the union of carbon and sulphur to form carbon disulphide (CS_2). Carbon is the well-known black solid represented by lamp-black, or charcoal, and sulphur is a tasteless and odorless yellow solid. When combined in the proportion of two of sulphur and one of carbon, the result is a colorless substance instead of either black or yellow, liquid instead of solid, and having a strong and disagreeable odor.

Moreover, charcoal or sulphur alone may be eaten without harm, and are often taken as medicine, but when combined as carbon disulphide (CS_2), they are poisonous, and the suffocating gas which they produce is often used to destroy insects and other vermin. In numerous cases, the union or disintegration of two substances is influenced by a third which does not form a part of the substance produced. Thus, when manganese dioxide is mixed with potassium chlorate and heated, the latter gives up its oxygen much more readily than it would by itself. Substances that influence chemical action in this way are called *catalyzers*.

33. Proportions of Elements in Compounds.—In forming the molecules of a substance, the chemical elements unite with one another in definite and unvarying proportions. It is this feature that makes the molecules of a given substance all alike, no matter how many chemical elements compose it. When carbon and oxygen unite to form carbon dioxide (CO_2), two atoms of oxygen always unite with one of carbon. Though great quantities of oxygen may be present, it does not affect the result; one atom of carbon will take on only two of oxygen. When oxygen is scarce however, one atom of carbon may unite with one atom of oxygen, forming carbon monoxide (CO). We see, therefore, that while the atoms of different chemical ele-

ments do not unite in haphazard proportions, they may unite in different, though definite, proportions to form different substances. The behavior of nitrogen and oxygen are instructive in this connection. Various combinations of these two elements form nitric oxide (NO), nitrous oxide (N_2O), nitrogen peroxide (NO_2), nitrogen trioxide (N_2O_3), and nitrogen pentoxide (N_2O_5). The first two are colorless gases the third is a red-brown gas, the fourth is a bluish-green liquid, and the last, a white solid, though all are made of different proportions of the same two colorless gases.

34. Chemical Affinity.—The force which causes various elements to combine, and holds them in their compounds, is called *chemical affinity*. This property is probably electrical in its nature. Chemical affinity does not act with equal force in all combinations, for in some the atoms are so weakly held together that they separate if the compound is left standing for any length of time. In this way, hydrogen peroxide (H_2O_2) loses one of its atoms of oxygen and becomes merely water (H_2O). This is the reason that peroxide of hydrogen, as it is called, spoils if left exposed to the air for any length of time. In other gases, one chemical may displace another in a compound when associated with it. For instance, when hydrochloric acid (HCl) is poured on limestone ($CaCO_3$), carbon dioxide (CO_2) is liberated, and the other atoms form chloride of lime and water, according to the equation $2HCl + CaCO_3 = CO_2 + CaCl_2 + H_2O$. When hydrochloric acid is poured on zinc, the chlorine unites with the zinc, forming zinc chloride ($ZnCl_2$) and the hydrogen is released as a gas. By a similar process, iron is reduced from its ores. Ordinary iron ores are oxides combined with iron. When such ores are mixed with carbon and heated, the carbon unites with the oxygen leaving the iron free. When the molecules of a substance are acted upon in such a way as to make one or more new substances by a rearrangement of the atoms, we speak of the change as a *chem-*

ical reaction. The burning of wood is another illustration of chemical reaction. The formula for cellulose of which the wood is composed is $(C_6H_{10}O_5)$. In burning, the oxygen unites with the carbon to form carbon dioxide (CO_2), leaving the other elements to form water. When iron rusts some of the oxygen in the air unites with the atoms of iron, and actually makes it heavier.

35. Heat and Chemical Change.—Heat is concerned in all chemical reactions and either appears or disappears when the reaction takes place. At very low temperatures, all chemical

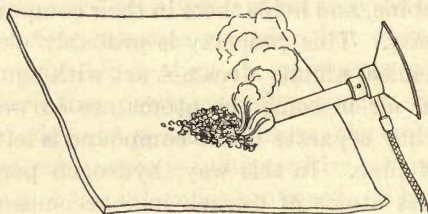


FIG. 4.—Setting fire to zinc and sulphur on piece of asbestos paper.

action ceases. In some cases, heat is necessary to make the elements unite; in other cases, heat applied to a substance will cause it to break up into its elements again; and in still other cases, the union of the chemical elements gives off heat. The union of hydrogen and carbon produces more heat than the union of any other elements. The union of carbon and oxygen, as in the burning of wood and coal also gives off much heat. Sulphur and oxygen uniting give off much less heat and phosphorus and oxygen still less. Respiration is a familiar example of the appearance of heat with chemical change, the heat being due to the union of oxygen with the carbon in our bodies. Calcium carbide, used in making acetylene gas, takes in much heat energy when it is formed, but gives it off again when the gas produced from it is burned. The rare element, radium, has

the peculiar property of giving out heat and always remaining about five degrees warmer than its surroundings. The energy of light may, like heat, effect chemical changes. Hydrogen and chlorine, mixed in darkness, give no reaction, but a ray of strong light will cause them to unite with explosive violence. It is also the chemical energy of light that affects the silver salts of photographic films and plates and causes the pictures to appear. Light also causes the disintegration of hydrogen peroxide which accounts for its being kept in brown bottles and in darkness. Energy of a similar nature causes our skin to tan in strong sunlight.

Practical Exercises

1. Consult the table of chemical elements and make a list of all of those with which you are familiar.

2. Make a list of all the uncombined chemical elements that you can find in the school room.

3. Write after the names in the following list the correct chemical symbols:

Iodine

Potassium

Iron

Carbon

Oxygen

Zinc

Mercury

Gold

Chlorine

Tungsten

Sodium

Calcium

4. Write after the names of the following, the chemical elements of which they are composed:

Limestone (CaCO_3)

Washing soda (Na_2CO_3)

Table salt (NaCl)

Calcium chloride (CaCl_2)

Sulphuric Acid (H_2SO_4)

5. Thoroughly mix one-quarter of a teaspoonful of powdered zinc and an equal amount of powdered sulphur. Place these on a piece of asbestos paper and apply heat from above by means of a bunsen burner held at

arm's length. The chemical reaction will produce zinc sulphide. Is this an element or a compound? Why?

6. Of what use was heat in the foregoing experiment?
7. Can you write the formula for zinc sulphide?
8. Place a small quantity of mercuric oxide (HgO) in a test-tube, and heat strongly. What change in the color of the substance do you notice?
9. What is left in the cooler part of the test tube after it is heated?
10. What becomes of the other element?
11. What did the application of heat do in this experiment?
12. How did this experiment differ from that in question 5?
13. When a ton of wood is burned more than a ton of gas goes up the chimney. How do you explain this?
14. Why is it necessary to know the temperature of the solutions when developing films, prints, and negatives in photography?
15. Of what use is heat in cooking food other than softening the food and killing the germs?

CHAPTER VI

THE MEASUREMENT OF MATTER

36. Standards.—Many times each day we have occasion to measure matter in various ways. Such questions as how much, how long, or how heavy, are continually on our tongues. Nearly all buying and selling involves questions of the measurement of matter. The system of measurement with which we are, at present, most familiar makes use of such units as feet, yards, miles, quarts, bushels, tons, pounds, and the like, and these are subdivided entirely without regard to uniformity, so that we have to remember a great variety of special numbers, containing fractions equally lacking in uniformity. There are, for instance, $5\frac{1}{2}$ yards in a rod, $24\frac{3}{4}$ cubic feet in a perch, while the numbers that we use in square measurement are 144, 9, $30\frac{1}{4}$, 160, and 640. On this account it has always been a difficult task to learn the different tables of measurement, and to work problems in them. Even scientists were bothered by these difficult tables and long ago invented a better system. This latter is called the metric system, and it is the one in common use in practically all civilized countries except England and the United States. In our own country, the use of this system has been legal since 1866, and though the old, or English, system is still the common one, the new system is fast gaining in favor, and is practically the only one now used in scientific laboratories. So important has the metric system become, that in 1893 two of its units, the meter and the kilogram, were adopted as the legal fundamental standards, and our yard and pound are now actually standardized by comparison with them.

37. The Advantage of the Metric System.—The great advantage of the metric system is that it is a decimal system, in which ten of one denomination makes one of the next higher, exactly as in our coinage. This renders it easy to make calculations of various kinds, since one denomination may be changed into terms of another by multiplying or dividing by tens, hundreds or thousands. Moreover, in the English system, we cannot conveniently express low denominations as fractions of higher ones. In the metric system, however, we have but to set the quantities down in their order and insert a decimal point at the proper place. In this system, all the tables one will ever need in measuring lengths, surfaces, weights, and volumes may be learned in a single morning instead of requiring months for the study of the tables as in the English system.

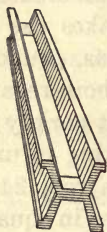


FIG. 5.—The standard meter. (Tower, Smith and Turton.)

38. The Meter.—The meter from which the metric system takes its name is the standard of length. At the time it was established, it was intended to be one ten-millionth of the distance from the equator to the pole, or the forty-millionth part of a great circle or meridian. It is, therefore, a little more than three feet in length (39.37 inches). For practical purposes, it is defined as the distance, at the temperature of melting ice, between two lines ruled on a certain bar of platinum and iridium which is kept at the International Bureau of Weights and Measures near Paris. Accurate copies of this bar are preserved at Washington and at the capitals of many other countries and serve as standards with which other measuring instruments may be compared. Owing to the difficulty of exactly reproducing these standard meters by ordinary measurements, if lost or destroyed, it is now proposed to designate a certain number of light waves as the length of a meter. These light

waves are unvarying and the exact length of a meter can, therefore, be found at any time.

39. Divisions of the Metric System.—The meter is divided into tenths (*decimeters*), hundredths (*centimeters*), and thousandths (*millimeters*), the names of these divisions being made by using the Latin prefixes *deci* (10) *centi* (100), and *milli* (1000). The words dime, cent, and mill in our coinage have the same significance. Multiples of the meter have names made by using the Greek prefixes. Thus ten meters is a *deka-meter*, one hundred meters a *hectometer*, and one thousand meters a *kilometer*. Of these larger divisions, the kilometer is the only one commonly used, smaller lengths being expressed in meters or its divisions, especially centimeters and milli-

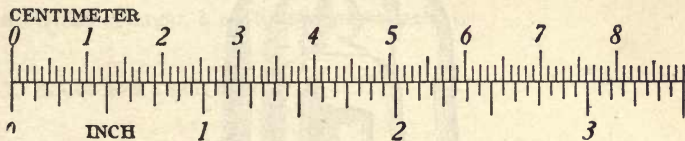


FIG. 6.—Centimeter and inch scales. (Tower, Smith and Turton.)

meters. In the measurement of surfaces, since two dimensions are involved, one hundred (10×10) of one division makes one of the next. Thus 100 square centimeters makes a square decimeter, and 100 square decimeters makes a square meter.

40. Grams and Liters.—The unit of weight in the metric system is designated as the weight of a cubic centimeter of pure water at its greatest density ($4^{\circ}\text{C}.$). This unit is called the *gram*. We can get some idea of the weight of a gram by remembering that our five-cent coin or nickel weighs five grams. Like the meter, the gram is divided into tenths, hundredths, and thousandths, and the names of the divisions are formed by using the same prefixes. A thousandth of a gram, therefore, is a *milligram* and a thousand grams is a *kilo-*

gram. The latter is commonly abbreviated to *kilo*. One thousand kilograms is called a *metric ton*. The standard of volume (or size) is the *liter* (pronounced leeter). It is equal to a thousand ($10 \times 10 \times 10$) cubic centimeters. The divisions and multiples of the liter are the same as in the other standards. The denominations most commonly used are the liter and the hectoliter. Instead of milliliters small quantities are usually expressed in cubic centimeters which are the equivalent of milliliters. Instead of the *kiloliter* its equivalent, the

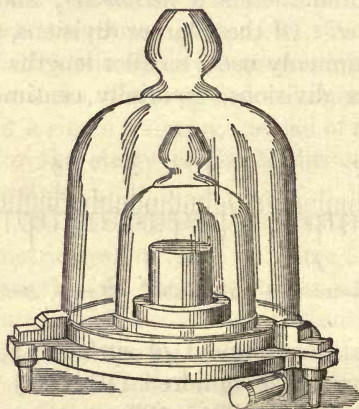


FIG. 7.—Standard kilogram. (*Black and Davis.*)

cubic meter, is more frequently used. Copies of the standard kilogram and of the liter are preserved at the Bureau of Standards at Washington. This Bureau is also charged with a general supervision of our weights and measures. It not only furnishes correct standards of measures for length, weight, and volume, but also supplies standard *thermometers*, *pyrometers*, *photometers* and many others.

Practical Exercises

1. Construct the table of lengths beginning with the millimeter and ending with the kilometer as follows:

10 millimeters equal 1 centimeter

10 centimeters equal 1, etc.

2. Construct a table of weights beginning with a milligram.
3. Construct a table of volumes.
4. Examine a meter stick and find out how many inches there are in a meter.
5. What unit of measurement in the English system is the meter nearest in length?
6. Which is larger, a centimeter or an inch?
7. About how much larger?
8. Which is larger, a dekameter or a decimeter? How much larger?
9. Which is the greater distance, a kilometer or a mile? (Reduce to feet or meters for comparison.)
10. How many feet farther? How many meters farther?
11. How many square millimeters in a square centimeter?
12. Using a pair of scales, compare a gram weight with an ounce. Which is heavier? How much heavier?
13. Which is heavier, a kilogram or a pound? How much heavier? (Make this calculation from what you know of the comparative weight of grams and ounces.)



FIG. 8.—A
graduate for
measuring
liquids.

14. By means of a graduate, measure out 10 cubic centimeters of water. Is it more or less than a spoonful?

15. How many cubic centimeters in the spoon you used?

16. Examine a liter measure. What unit in the English system is the liter nearest in size?

17. How many centimeters in 5 meters?

18. How many milligrams in 2 grams?

19. How many liters in a kiloliter?

20. How many grams in 10 kilograms?

CHAPTER VII

DENSITY AND SPECIFIC GRAVITY

41. Weight.—It is a matter of common observation that all objects of the same size are not equal in weight. A piece of iron is much heavier than a piece of cork of the same volume. We explain this by saying that iron is denser than cork; that is, that a given volume of iron has more matter in it than an equal volume of cork. Since heating a substance causes its molecules to move farther apart, we infer that a given volume of a substance in the gaseous state will weigh less than the same volume of it in the solid form, and this is found to be exactly the case. It weighs less because there are fewer molecules of it in a given volume. This is the reason warm air rises. Heating it causes it to be less dense and therefore lighter, and it is then pushed up by the surrounding cooler and heavier air. We must not confuse *density* and *weight*, however. The *mass* of a body is the amount of matter in it and this depends upon its density, but the weight of a body is simply the pull of the earth upon it, which, owing to the shape of the earth, may differ in different places. For instance, an object weighing 589 pounds at the equator would weigh 590 pounds at the poles. A body weighing 100 pounds on the earth would weigh nearly $1\frac{1}{2}$ tons on the sun.

42. How Density is Measured.—In order to measure a thing, we must have a standard with which to compare it. The standard for measuring the density of gases is usually the air at the temperature of melting ice. For measuring the density of solids and liquids, water is taken as a standard. This latter makes a most convenient standard since it has been

agreed that a cubic centimeter of water, when at its greatest density, weighs a gram. If we know the density of a substance, that is, if we know how much a cubic centimeter of it weighs in comparison with water, we can easily ascertain its weight by finding its volume in cubic centimeters and multiplying this by its density. Suppose for instance that a body has a density of 5. This means that a cubic centimeter of it weighs five times as much as a cubic centimeter of water, or five grams. If we had a volume of ten cubic centimeters, it would weigh 5 times 10, or 50 grams. The density of a solid may be determined in the first place by weighing it in air and again in water. The second weighing is accomplished by attaching it to a balance in such a way that it is immersed in the water during the weighing. A substance weighed in water weighs less than it does in air, and this difference in weight is the weight of the water it displaces when immersed. In this way, we find the weight of a volume of water equal to the volume of the solid, and when this is compared with its weight in air, we have its density. Suppose the weight in air of a given substance to be 9 grams, and a loss of 3 grams in weight is discovered when it is weighed in water. It is very evident that the water it displaced must weigh 3 grams, and that the substance is therefore three times as heavy as the same volume of water; that is, it has a density of 3. Though it is usually more convenient to express density in grams per cubic centimeter, we are not confined to that manner of expression since density is a relative term. It can be as easily expressed in grams per cubic foot, cubic inch, or other volumes. Gold has a density of 19.3, therefore a cubic foot of gold would weigh 19.3 times as much as a cubic foot of water, and a cubic yard of gold would of course be 19.3 times as heavy as a cubic yard of water.

43. Specific Gravity.—The term *specific gravity* is often used to indicate the weight of substances in comparison with

equal bulks of water. The heavier the substance, the greater its specific gravity is said to be. This term, however, is rapidly passing out of use since the unit of mass in the metric system is defined as the weight of a cubic centimeter of water at its greatest density. In this system, therefore, the true density of a body and its density with reference to water is the same thing. The density of liquids is often measured by a *specific gravity bottle* made of thin glass. This is first weighed when empty, then when filled with water, and again when

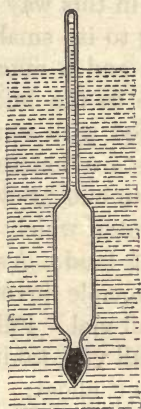


FIG. 9.—Common hydrometer. (Duff.) FIG. 10.—Specific gravity bottle

filled with the liquid to be tested. In this way, the weights of the two liquids are easily compared. A common way of measuring the density of a liquid is by means of a *hydrometer* which is essentially a sealed glass tube so weighted that it will sink to a certain depth in pure water. In liquids more dense than water, it will of course not sink so deep, and in lighter liquids it will sink deeper. By means of a scale on the tube, the differences and therefore the densities, are indicated. Hydrometers for measuring single liquids have special names which are often self-explanatory; as *alcoholometer*, *saccharome-*

ter, lactometer, and salimeter. Since the purity of a substance has a close relation to its density, these special forms of hydrometers are much used commercially in fixing the value of liquids.

44. Buoyancy.—When a body sinks in a medium lighter than itself, the medium in which it sinks pushes upward on the body with a force exactly equal to the weight of the medium displaced. This force pushing upward is called *buoyancy*, and a body which is supported in this way is said to be *buoyant*. Cork, owing to its small density, is very buoyant in water, and is much used in life-preservers. It is due to the buoyancy of the air, that balloons, filled with some lighter gas, rise in it, and balloons are therefore said to be buoyant. It is owing to buoyancy also that one can lift a stone in water which he would find impossible to move on land. An instructive illustration of the principle involved may be made of a good-sized bottle and a small vial. Fill the large bottle with water and invert in it the small vial, taking care to have just enough air in the latter to keep it afloat. When the large bottle is full of water and the cork pushed in, it will com-



FIG. 11.—The diving vial (small vial in large bottle of water).

be made of a good-sized bottle and a small vial. Fill the large bottle with water and invert in it the small vial, taking care to have just enough air in the latter to keep it afloat. When the large bottle is full of water and the cork pushed in, it will com-

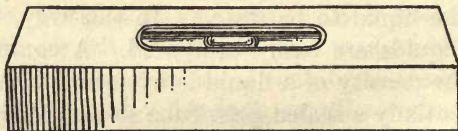


FIG. 12.—Spirit level.

press the air in the vial, make more room for the water, and cause it to sink. Removing the pressure will allow the air in the small vial to expand and push out some of the water making it lighter and causing it to rise to the surface. Submarines

are maneuvered under water by varying the weight of the boat in a somewhat similar way. The *spirit level* used by carpenters and masons consists essentially of a glass tube full of liquid, except for a small bubble of air. This air being lighter than the liquid, always comes to the top. When the tube in its setting is placed on a level surface the bubble will of course come to rest exactly in the middle of the tube. Any variation from this position indicates a surface that is not level.

TABLE OF DENSITIES

Alcohol.....	.79	Mercury.....	13.60
Aluminum	2.58	Lead.....	11.30
Copper.....	8.80	Nickel.....	8.90
Cork.....	.24	Oak.....	.80
Glass.....	2.60	Olive oil.....	.91
Cast iron.....	7.40	Silver.....	10.53
Chloroform.....	1.52	Tin.....	7.29
Ether.....	.72	Zinc.....	7.15
Carbon dioxide..	.001978	Nitrogen.....	.001256
Hydrogen.....	.0000896	Oxygen.....	.00143

Practical Exercises

1. Fill a graduate half full of water, and drop into it any convenient piece of metal, finding the volume by noting carefully the amount of water it displaces. Then weigh the metal. Assuming that every cubic centimeter of water displaced weighs a gram, does the weight of the metal justify the specific gravity assigned to it in the table?

2. Which is heavier gold or silver? How much heavier?

3. The density of brass is 8.5. How many centimeters of water would be necessary to exactly balance 4 cubic centimeters of brass?

4. How many grams would 10 cc. of platinum weigh if the density of platinum is 21.5?

5. A cubic foot of water weighs 62.3 pounds. Could you carry a cubic foot of gold? How much would it weigh?

6. Aluminum is often called a light metal. Will it float or sink in water?

7. A vessel 10 by 10 by 10 cc. in size would hold how many grams of water?

8. How many grams of mercury would the above-mentioned vessel hold?

9. Find the weight of a liter of alcohol.

10. How much heavier is a cubic centimeter of iron than one of cork?

11. Which has the greater specific gravity, cream or milk? How do you know?

12. Which weighs more, a cubic centimeter of ice or a cubic centimeter of water. How do you know?

13. Do you infer that ice has or has not a density greater than 1?

14. Why does olive oil float on water?

15. Will iron float or sink in mercury? Why?

16. Housewives often test the strength of brine by putting an egg in it. An egg will sink in pure water. Explain why it will float in brine.

17. When the smoke from chimneys does not rise readily, is the air light or heavy? How do you know?

18. In which would a boat sink deeper, a river or the ocean?
19. If the ice man leaves a piece of ice 50 by 40 by 10 cm. in size has he left 50 pounds or not? (Ice has a specific gravity of .9.)
20. A liter of hydrogen weighs about .09 gram. How much heavier is water than hydrogen?
21. If a body sinks half of its volume in water, what is its specific gravity?
22. What is its specific gravity if it sinks half its volume in mercury?
23. In which should it be easier to swim, salt or fresh water? Why?
24. With what force does gravity attract a kilogram weight?

CHAPTER VIII

THE MEASUREMENT OF TEMPERATURE

45. How Measured.—In the measurement of temperature, we have to deal with the effects of an addition of energy to matter. It is more convenient to measure the effect of energy upon matter than to measure the energy direct. The instrument with which we now ascertain the temperature of an object is called a *thermometer*. This instrument was not invented until about a hundred years after Columbus discovered America. Before that time, people had to depend upon their bodily feelings for information of this nature and such methods are still in use for roughly estimating temperature, as when we touch an object with the hand to see if it is warm or cold. This, however, is a very unreliable method of testing because our temperature sense is easily deceived. If we hold one hand in a basin of hot water for a time and the other hand in a basin of cold water, and then put both hands into a vessel of water at room temperature, the hand that was in the hot water will now feel cold and the one that was in the cold water will feel warm, though they are both in water of the same temperature (§83).

46. The Therommeter.—Thermometers may be made of any substance that expands and contracts quickly with variations in temperature, but the substances most used are mercury and alcohol. The ordinary thermometer consists of a slender glass tube closed at the upper end, with a bulb at the lower end containing either of the two liquids mentioned. If alcohol is used, it is generally colored so that it may be more

easily seen. A scale, by means of which the changes may be read, is either marked on the glass tube or firmly attached to it. The scale is marked off in many small divisions called degrees, which serve as units of measurement.

47. Graduating the Thermometer.—Before the thermometer can be used, the scale must be adjusted to the height of the liquid in the tube. In making this adjustment, two convenient fixed points from which to measure are found in the temperature at which water boils and the temperature at which it freezes. After the liquid has been put into the tube, the bulb is placed in melting ice which causes the column of liquid to contract and shorten. The point where the top of the column comes to rest is marked *freezing*. Then the bulb is placed in the steam from water boiling under certain standard conditions until the liquid column again comes to rest. This point is marked *boiling*. The distance between the two points is then marked off in degrees. Cheap thermometers are made with less care and their temperature points determined by comparison with the scale of a more exact instrument. The ordinary thermometer is called a *Fahrenheit* thermometer after the man who invented it. On this thermometer, the scale begins at a point called *zero* (0) which is 32 degrees below the freezing point. The boiling point is marked 212, thus making 180 degrees between the freezing and boiling points. A much better scale is that called the *Centigrade* scale in which the freezing point is marked zero and the boiling point 100. This is a decimal scale similar to others already studied and is used almost universally for scientific work. Its employment for other uses is steadily increas-

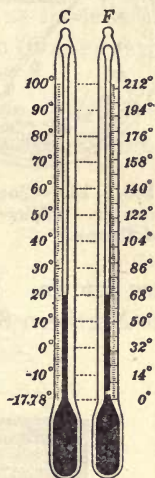


FIG. 13.—Centigrade and Fahrenheit thermometers. (Tower, Smith and Turton.)

ing and in time it is probable that it will completely displace the Fahrenheit scale. It is to be noted that the differences in these two scales are not differences in temperature but merely differences in methods of measuring.

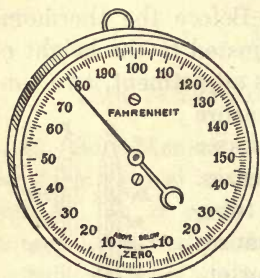


FIG. 14.—Clock thermometer. (Tower, Smith and Turton.)

Thirty-two degrees above zero Fahrenheit (32°F.) is the same as zero Centigrade (0°C.). Thermometers are frequently made with both scales marked on them.

48. Absolute Zero.—The maker of the Fahrenheit thermometer appears to have assumed that nothing could be colder than 32 degrees below the freezing point of water, and for this reason he called that point zero. Temperatures much below zero are now known. Even the temperature of the air in winter in the Northern States may go several degrees below this point.

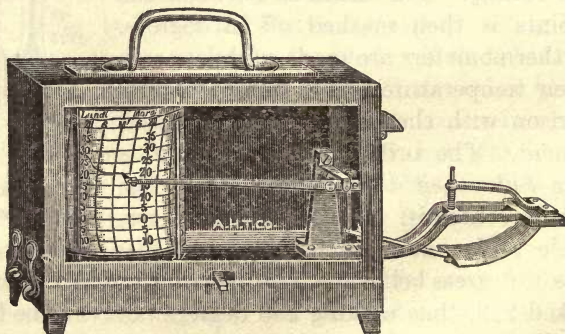


FIG. 15.—A recording thermograph.

It is obvious, however, that an object cannot go on losing heat forever. Sooner or later the last trace of heat disappears and all molecular motion ceases. This point is called

absolute zero. Temperatures of absolute zero have never been reached on the earth, but from the fact that all gases contract one two-hundred-and-seventy-third of their volume at 0°C . for each Centigrade degree of further cooling, it is inferred that absolute zero must be 273 degrees below the zero of the Centigrade scale, or as we commonly express it -273°C . A third temperature scale called the *absolute scale* begins at the absolute zero and has degrees of the same size as those in the Centigrade scale. On this scale, therefore, the freezing point of water is 273° above zero.

49. Changing from Fahrenheit to Centigrade.—With two thermometer scales in common use, it frequently becomes

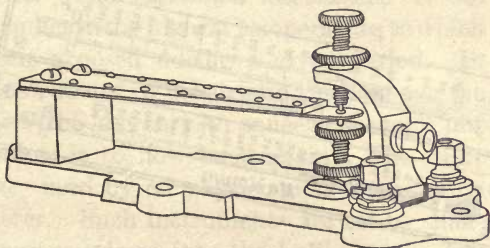


FIG. 16.—Thermostat.

necessary to change temperatures from one scale to the other. This is easily done when the relative size of the degrees is considered. From the fact that there are 180 degrees between freezing and boiling on the Fahrenheit scale and only 100 on the Centigrade, we perceive that the ratio of the sizes of the two degrees must be as 180 is to 100; that is, the Fahrenheit degree is five-ninths of a Centigrade degree. Therefore, to change Fahrenheit degrees to Centigrade degrees, we multiply by $\frac{5}{9}$, and to change Centigrade to Fahrenheit we multiply by $\frac{9}{5}$. This, however, is done only when comparing the degrees. In matters of temperature, we must make allowance for the difference in the zeros of the two scales. Thus, when

we turn Fahrenheit degrees to Centigrade, we must subtract 32 degrees before multiplying by $\frac{5}{9}$ and, in the reverse process, we add 32 *after* we have multiplied by $\frac{9}{5}$. A convenient expression of this method is as follows: $(C. \times \frac{9}{5}) + 32 = F.$ and $(F. - 32) \times \frac{5}{9} = C.$ For temperatures below zero Centigrade, 32 degrees must be subtracted after the change to Fahrenheit is made, but when changing in the other direction 32 must first be added for all temperatures below zero Fahrenheit.

50. Other Thermometers.—Long before the temperature of absolute zero is reached, alcohol and mercury become solid and are therefore not adapted to measuring extremely low

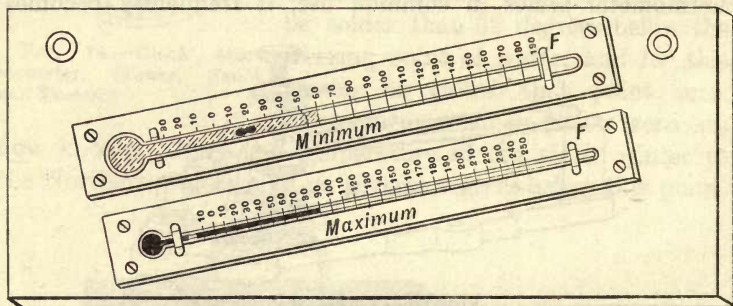


FIG. 17.—Maximum and minimum thermometers. (Duff.)

temperatures. In the other direction, there are temperatures much higher than boiling water, boiling alcohol, or even boiling mercury. For measuring such temperatures, other thermometers are needed. One instrument makes use of nitrogen or hydrogen gas. Since the pressure of a gas is proportional to its temperature, any difference in pressure may be translated into differences of temperature. The *clock thermometer* indicates the temperature by means of a pointer moving over a dial. The motion is given to the pointer by strips of two different metals fastened together. These metals have different rates of contracting and expanding and thus bend each other back

and forth with changes in temperature and so move the pointer. The *thermostat* so often used in regulating the temperature of buildings makes use of a thermometer of this kind. As the temperature changes, the moving tip opens or closes an electric circuit which operates the dampers of the heating system. When the pointer carries a pen and makes a continuous record on a moving strip of paper, it is called a *thermograph*. The indicator of the thermograph may also be moved by the expansion of alcohol in a flattened and curved metal tube. When the alcohol expands, the tube is straightened out and this moves the pointer. The *maximum thermometer* is designed to indicate the highest temperature to which it has been exposed during a given period. In such an instrument, a constriction just above the bulb allows the mercury to squeeze through but will not allow it to flow back again. The *clinic thermometer* used by all physicians is a maximum thermometer. Such instruments are set by shaking the mercury down into the bulb again. The *minimum thermometer* is an alcohol thermometer having a small indicator in the tube which is drawn down as the alcohol recedes but is not pushed upward when the alcohol rises. The minimum thermometer must be placed in a nearly horizontal position. Its index may be set with a magnet or by giving the instrument a slight jar.



FIG. 18.—
Clinical thermometer.
(Duff.)

Practical Exercises

1. Examine the nearest thermometer. Is it made with mercury or alcohol?
2. How many Centigrade degrees equal 45 Fahrenheit degrees?

3. How many Fahrenheit degrees equal 40 Centigrade degrees?
4. Find the temperature of the school room in Fahrenheit degrees and change to Centigrade temperature.
5. Express the temperature of the blood in Centigrade degrees.
6. Water at the temperature of 4°C . is at its greatest density. What temperature on the Fahrenheit scale is this?
7. The protoplasm of living parts of plants is killed at about 122°F . At what temperature Centigrade are plants killed?
8. Mercury boils at 357°C . How hot is this on the Fahrenheit scale?
9. What temperature is 0°F . on the Centigrade scale?
10. What is the highest point reached by the Fahrenheit thermometer in summer in your region? What is the lowest point reached in winter? How many Centigrade degrees would this difference equal?
11. White-hot iron has a temperature of about 2200°F . What is its temperature Centigrade?
12. The temperature of the electric furnace is about 4000°C . How hot is this on the Fahrenheit scale?
13. Most seeds will not sprout until the temperature reaches 41°F . How warm is this on the Centigrade scale?
14. What temperature is absolute zero on the Fahrenheit scale?

15. What would be the temperature of boiling water in Centigrade degrees if the Centigrade scale began at absolute zero?

16. What would be the temperature of boiling mercury on the absolute scale?

17. What temperature is -40°C. on the Fahrenheit scale?

18. If the thermometer bulb were made of a substance that expands faster than mercury, what effect would this have on the column of mercury?

19. When the thermometer bulb is plunged into hot water the mercury at first falls. Why?

20. The temperature of the sun is estimated to be about 7000°C. How hot is this on the Fahrenheit scale?

CHAPTER IX

EFFECT OF HEAT ON VOLUME

51. Cohesion.—The force which attracts the molecules of a substance to one another is called cohesion. It is this force which we must overcome in splitting or pulling a thing apart, and which gives hardness, definite shape, and solidity to different substances. Heat weakens cohesion by increasing the speed of the molecules and causing them to move farther apart. Liquids when heated expand or increase in volume more readily than solids, and gases more readily than either. When heat is withdrawn from a body, cohesion draws the molecules together again and causes it to contract.

52. Melting Point.—If sufficient heat is added to a solid, a point is finally reached when cohesion is overbalanced. The substance then ceases to have a definite shape and, breaking down, becomes a liquid, or as we say, it *melts*. It is not possible to say in advance at what temperature an unknown substance will melt, but when this point is once determined, we may be sure that the substance will always melt at this temperature under similar conditions. Different substances, as might be assumed, have different melting points, but these points for each substance do not vary unless the conditions are changed. Crystalline substances, that is, those which form crystals on solidifying, show most sharply the changes from the solid to the liquid state. A few substances such as glass, pitch and wax, do not have definite melting points but slowly soften under the influence of heat and form a pasty mass. On the other hand, certain other substances, such as iodine and camphor, do not melt at all under ordinary conditions but appear

to jump at once from a solid to a gas. Such a change of state is called *sublimation* (§89). At low temperatures, even ice may sublime. When gases of this kind are sufficiently cooled, they return directly to the solid state. Under proper conditions however, these substances may also be made to assume the liquid state.

53. Expansion of Gases.—If sufficient heat is added to a liquid it becomes a gas. When water assumes this condition, we say it has *evaporated*. While liquids are known to occupy more space than the solids from which they were made, the most conspicuous examples of increase of volume with change of state are found among the gases. Water turned to gas (steam) increases more than 1600 times its volume. Engineers roughly express it by saying that “A cubic inch of water makes a cubic foot of steam.” Another familiar example of a solid that takes up much space when turned to gas is gunpowder.

54. Effects of Withdrawing Heat.—Withdrawing heat from a substance has exactly the opposite effect upon its volume that heating it has. All gases may be made liquid by withdrawing heat, but the process is hastened by pressure. With a reduction in temperature there always goes a reduction in volume, and this reduction continues through the liquid and solid states of practically all substances. Water, however, is a conspicuous and important exception. Solid water (ice), like other solids, contracts with a lowering of the temperature, and liquid water contracts like other liquids, but just before the point at which it turns from a liquid to a solid is reached (about $4^{\circ}\text{C}.$), it begins to expand, and as it turns to a solid, it exerts a pressure of more than 100 tons to the square foot. This pressure is sufficient to burst water pipes, split open rocks, and disturb the foundations of buildings. It is to be observed that the pressure is exerted only at the instant of becoming solid. After this condition is reached, ice contracts with loss of heat, as other substances do.

55. Casting.—A large number of metal objects are hammered into shape but the majority are “cast” by being melted and poured into moulds. Sharp castings cannot be made of most metals for the reason that they contract on solidifying. Brass and cast iron are two common substances that expand slightly in turning from the liquid to the solid state and so are prime favorites with the foundryman. Type metal is a mixture of various metals that expands on solidifying, though the metals alone contract on cooling. The expansion of type metal is highly desirable; in fact, the several metals composing it are selected with this end in view, for if it did not expand on solidifying, it would not fill the moulds and form the sharp outlines so necessary for type. Gold and silver, on the contrary, contract on solidifying, and coins cannot be cast of

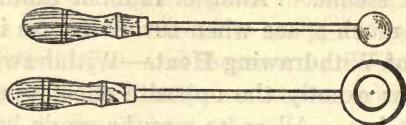


FIG. 19.—Ring and ball set.

these metals. When coins are made, therefore, pieces of the metal have to be forced into dies under great pressure to give them the proper sharpness. Of all the common metals, zinc contracts most when heat is withdrawn.

56. Some Practical Applications.—The expansion and contraction of all substances with changes of temperature make it necessary to take this into account daily in many operations. Sometimes we take advantage of it, as when steel girders are fastened together with red-hot rivets which contract and tighten as they cool; sometimes considerable ingenuity must be developed to avoid its effects. Large steel bridges expand so much in the summer sunshine that the sections are mounted on rollers or have telescoping joints to permit them to change in length. Long bridges sometimes vary more than a foot in length in

a day. In stringing telegraph, telephone, and other wires, the temperature must also be considered. If drawn too tight on a hot day the wires may shorten and snap on a cold one. Long runs of steam pipes have to have "expansion joints" at intervals to take up the extra length of the pipe when heated. In late fall and early spring, plants are often killed by being "heaved by the frost." That is, during a thaw, water accumulates about them and in freezing expands and lifts them out of the ground. In the same way, foundations may be damaged if they are not carried down into the earth below the frost line. Expansion caused by the frost breaks up rocks into soil and makes plant growth possible. Land is often plowed late in fall to permit of this mellowing action of the frost. Since solids and liquids differ from gases and do not expand alike, it is often necessary to make a nice choice of materials in order to insure the proper working of our machines. Invar, a compound of steel and nickel, often called nickel-steel, expands very little with changes of temperature and is therefore an ideal substance from which to make measuring instruments, clock pendulums, scales, and the like. If pendulums were made of ordinary metals they would be too long in summer and cause the clock to run slow. In winter with the same pendulum the clock would run too fast.

In good clocks, the pendulum is often made of two different metals with different rates of expansion so that one counteracts the effects of the other. Alcohol and mercury, on the other hand, rapidly change in volume with changes in temperature and thus are useful in thermometers. In electric light bulbs the current must be carried to the filament by

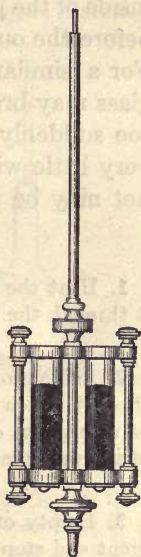


FIG. 20.—Compensated mercury pendulum. (Black and Davis.)

wires which have practically the same rate of expansion as the glass bulbs themselves. Platinum, though very expensive, is the most suitable metal for this purpose since it expands and contracts at nearly the same rate as glass. Other metals would contract and let air into the bulb or expand and break it. In pouring hot liquids into glass, as in canning, the inside of the jar often expands so rapidly that the jar is cracked before the outside can become heated and expand to match it. For a similar reason a drop of cold water splashed on a hot glass may break it by causing the part to cool and contract too suddenly. Crucibles made of quartz expand and contract very little with changes of temperature and when heated red hot may be plunged into water without being broken.

Practical Exercises

1. Heat the ball of a ring-and-ball set for a short time and try to pass it through the ring. Explain the effect noted.
2. Fill a florence flask with water and cork with a one-hole stopper through which passes a close-fitting glass tube. Put the flask on a piece of wire gauze over a bunsen burner and heat. Explain the movement of the water in the tube.
3. Empty out the water from the flask used in the preceding experiment and stop up the glass tube with a drop of any liquid. Warm the flask by holding the hand upon it. Explain the results noted.
4. Hold the mouth of a tall cylinder or large bottle at some distance above a flame until the air within has been thoroughly warmed. Then quickly place the vessel, mouth down, in a dish of water. Explain how the cooling of the air in the vessel makes more room for water in it.
5. Could one make a thermometer of water?
6. When the sun shines on a tall chimney or monument, will it bend toward or away from the sun? Why?

7. Why is it necessary in indicating the exact length of the standard meter to mention the temperature of the standard (§38)?

8. Give a reason for the space left between the ends of rails on railroads.

9. Stoppers sometimes become so firmly fixed in bottles that it is impossible to loosen them with the hands. Can you suggest a method of loosening them based on what you have learned in this lesson?

10. Given a liter of water at a temperature of 50° . Will it take up more or less space if heated to a temperature of 90° ?

11. Would heating have any effect on the total weight of water?

12. Would a cupful of water at 50° weigh as much as or more than a cupful of water heated to 90° ?

13. How do you think a cubic foot of air at zero would compare in weight with a cubic foot of air when the mercury stands at 100° ?

14. Would you expect to get a pound of water from a pound of ice?

15. Why may test-tubes, beakers and the like, made of thin glass, be heated without breaking, when fruit jars and tumblers cannot?

16. Would fruit jars be as likely to crack when hot liquids are put into them if the jars were slowly warmed to the temperature of the liquids first? Why?

17. From what you know of heat and its effects do you think cold is a form of energy or merely the absence of heat?

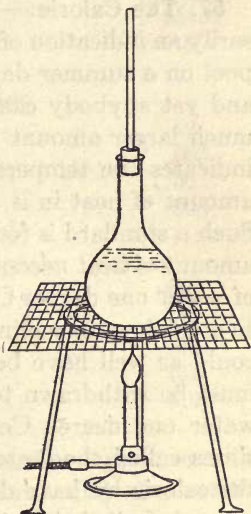


FIG. 21 — Wire gauze placed under glass flask when heating it.

CHAPTER X

HEAT AND CHANGE OF STATE

57. The Calorie.—The temperature of a body is not necessarily an indication of the amount of heat it contains. A small pool on a summer day may be warmer than the nearest lake, and yet anybody can understand that the lake must have a much larger amount of heat in it. The thermometer merely indicates the temperature of a body. To measure the total amount of heat in it, we need a new standard of comparison. Such a standard is found in the *calorie*, which is defined as the amount of heat necessary to raise the temperature of one gram of water one degree Centigrade. Since all substances give off as much heat in cooling as they took up in warming, our calorie could as well have been defined as the amount of heat that must be withdrawn to lower the temperature of one gram of water one degree Centigrade. Another unit of heat sometimes called the *large calorie* is a thousand times larger than the calorie we have discussed. This latter, however, is more properly called the *kilocalorie*.

58. Specific Heat.—When we add equal amounts of heat to equal weights of different substances, we discover that all do not increase in temperature at the same rate; that is, it takes more heat to raise a gram of some substances one degree in temperature than it does others. The amount of heat that will raise a kilogram of water one degree Centigrade will raise an equal weight of copper ten degrees, of silver or tin twenty degrees, and of mercury thirty degrees. Land heats up four times as fast as water. The amount of heat required to raise the temperature of any substance one degree in comparison

with the heat required to raise the same amount of water one degree is called its *specific heat*. Specific heat is like specific gravity in that water is taken as a standard for comparison.

TABLE OF BOILING POINTS IN CENTIGRADE DEGREES

Air.....	-180	Hydrogen.....	-253
Alcohol.....	78	Mercury.....	357
Ammonia.....	-34	Oxygen.....	-183
Ether.....	35	Sulphur.....	444.6
Lead.....	1525	Zinc.....	918

TABLE OF SPECIFIC HEATS

Alcohol.....	.60	Iron.....	.12
Aluminum.....	.22	Mercury.....	.033
Copper.....	.094	Water.....	1.00
Ice.....	.50	Zinc.....	.093

TABLE OF MELTING POINTS IN CENTIGRADE DEGREES

Alcohol.....	-130	Iron.....	1530
Aluminum.....	658	Mercury.....	-39
Brass.....	910	Silver.....	961
Copper.....	1083	Tin.....	232
Gold.....	1063	Zinc.....	419

With the exception of hydrogen, water has the highest specific heat of any known substance. It is this quality that makes water so valuable in steam and hot water heating, hot-water bags, and the like. The large amount of heat needed to raise it to the boiling point must all be given out before it can resume its original temperature. The high specific heat of water also has an important effect on the daily temperature. The moisture in the air, by warming and cooling slowly, prevents sudden or rapid changes in temperature. This also explains the mild climate of regions near large bodies of water. In summer they are cooler than places further inland because much of the heat goes to warm the water, and in winter they are warmer because the heat taken up by the water is now

given back to the air. The British Islands, though in the latitude of Labrador, have a much milder climate because of the Gulf Stream which flows past their shores. One reason why water puts out fires is because the heat needed to warm it reduces the temperature below the point at which the fire will burn.

59. Latent Heat.—Although a calorie of heat is said to raise a gram of water one degree Centigrade, when the boiling point is reached this statement needs qualifying. We then discover that the addition of another calorie does not turn the boiling water to steam, nor does it raise its temperature one degree; in fact, it is not until 536 more calories are added that the water will turn to steam, and then the steam is the same temperature as the boiling water. In other words, it requires 536 times as much heat to turn a gram of water to steam as it does to raise its temperature one degree. Five hundred and thirty-six calories seems thus to have disappeared or become *latent* during the change of state. When we recall the effect of heat on the motion of molecules, however, we realize that the heat energy has not really disappeared but is employed in holding the molecules farther apart. That this is true is shown by the fact that when the gas (steam) contracts and turns back to a liquid again, the 536 calories reappear as heat. A similar state of affairs exists at the point where water freezes. When a gram of water turns to ice, it gives off 80 calories, though the ice is then no colder than the water from which it was made. When the ice is melted, however, 80 calories of heat are required to be put into it to effect the change of state, and the water still has the temperature of zero; that is, 80 calories of heat have become latent in the process. In a certain sense, therefore, melting may be said to be a cooling process and freezing a warming process since in melting each gram of water absorbs 80 calories and in freezing it gives off this heat. All substances act like water with reference to heat when a change in state

occurs, though in none of them are such large quantities of heat involved. The heat which is absorbed or given out with a change of state is usually spoken of as *latent heat*. The scientists call it the *heat of fusion* when solids turn to liquids, and the *heat of vaporization* when liquids turn to gases. Though water at zero Centigrade ordinarily turns to ice when 80 calories of heat per gram are withdrawn from it, it is possible to cool it still more and have it remain liquid if it is not agitated. As soon as it is stirred, however, part of it turns to ice and the remainder returns to the temperature of zero. This is the way in which "anchor ice" is formed at the bottom of rivers. The water becomes super-cooled in the stretches of quiet water above a rapid and when the rapid is reached the movement of the water causes the formation of anchor ice which may frequently be seen clinging to the stones beneath the water.

TABLE OF LATENT HEATS

In boiling		In melting	
Air.....	47	Copper.....	30
Alcohol.....	206	Ice.....	80
Ether.....	91	Iron.....	35
Mercury.....	62	Platinum.....	27
Sulphur.....	262	Tin.....	14
Water.....	536		

60. Practical Applications.—In steam-heating systems, the water is turned to steam in a boiler located in the basement or other convenient place and is then carried in pipes to the rooms to be heated. In the radiators, it gives up its latent heat and becomes liquid again, then runs back to the boiler and is reheated. Something of the kind is provided by nature on a much larger scale in autumn evenings when the moisture in the air turns to fog and, in giving up its latent heat, protects tender vegetation from the cold. Farmers sometimes utilize the latent heat in water by placing tubs of the liquid in cellars

to prevent freezing. Not until the water in freezing has given up its latent heat is there danger to other things in the cellar.

Practical Exercises

1. When a substance is boiling, does the addition of more heat increase its temperature or merely cause it to boil faster?
2. How does this knowledge enable one to save gas in cooking?
3. How warm can ice be made? Why?
4. How would you attempt to make mercury solid?
5. How could iron be made liquid?
6. What do you infer as to the temperature of liquid air?
7. What inference do you make as to the temperature of liquid iron?
8. Would you expect the boiling point of liquid air to be above or below zero Fahrenheit?
9. In a substance which can exist in all three states, which has the most heat in it, the solid, the liquid, or the gaseous form?
10. Which contains the least heat?
11. Dissolve about 100 grams of sodium thiosulphate (the "hypo" of the photographer) in about 10 cubic centimeters of boiling water, heating until all is dissolved. Place in a florence flask, cover and set away until cool. Then drop into the liquid a crystal of the hypo. What effect has this on the state of the substance?
12. Account for the heat that appears in the foregoing experiment.

13. When snow falls the weather usually moderates. Why (§58)?
14. In a "double boiler," the receptacle containing the substance to be heated is placed in a larger vessel containing water. How does the water in the second vessel prevent the burning of the substance? (How warm can water be made in an open vessel?)
15. Liquid air in an open vessel cannot be made warmer than -182°C . Why?
16. Why do not all the ice and snow melt as soon as the temperature rises above the freezing point?
17. Which contains the more heat, 1000 gallons of boiling water or the nearest lake at zero? Explain.
18. How many calories will be required to raise the temperature of 10 grams of water five degrees Centigrade?
19. Which would require more heat, to melt five grams of ice or to raise five grams of water 50° in temperature?
20. If the temperature of 100 grams of boiling water is reduced twenty degrees how many calories are given off?
21. If 180 calories are taken from a gram of boiling water what will be its temperature?
22. Which has the greater amount of heat in it, 1000 cubic centimeters of water at 10°C . or 1000 cubic centimeters of iron at the same temperature?
23. Why is copper not as good as iron for making flat-irons used in ironing (§58)?
24. Why is an aluminum kettle better than an iron one for heating water?

CHAPTER XI

PRESSURE AND CHANGE OF STATE

61. Boiling Affected by Pressure.—In previous studies, we have discovered that heating a substance causes it to expand by pushing its molecules further apart. We know also that if the heating is continued long enough, most substances become gases and take up a much greater space (§53). When anything

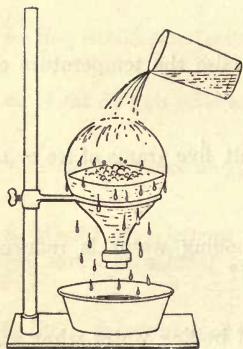


FIG. 22.—Boiling under diminished pressure effected by cooling air in bottom of flask.

happens to prevent this expansion, however, it naturally affects the change of state and requires much more heat to accomplish it. Under ordinary conditions, water boils at sea level at a temperature of $100^{\circ}\text{C}.$, but when the pressure of the air over water is doubled, we must raise the temperature to $121^{\circ}\text{C}.$ before boiling occurs. Reducing the pressure has of course the opposite effect. If the air over an evaporating liquid is pumped away, it will boil at a very low temperature; in fact, if the pressure is properly regulated water may be boiled and frozen at the same temperature.

In boiling syrup and other thick liquids, which there is danger of burning, they are often placed in closed vessels and the vapor pumped away. This not only lowers the boiling point but enables them to boil faster (§89, 104). An understanding of these facts enables us to ascertain the height of different places above sea level by simply boiling pure water there. As we ascend above sea level, we rise above part of the air

and thus the pressure is reduced and the boiling point is correspondingly lowered. Under ordinary conditions the boiling point is lowered 1°C . for each 960 feet above sea level. The change of solids to the liquid state is also affected by pressure. The interior of the earth is believed to be hot enough to melt all known rocks, and yet it cannot become liquid because of the enormous pressure upon it.

62. Compression of Gases.—Solids and liquids differ as regards the rate at which they expand when heated, but all gases expand alike. For a rise of 1°C . in temperature, they increase one two hundred and seventy-third of their volume at 0°C . Gases, being perfectly elastic, tend to expand indefinitely if unconfined, and when subjected to pressure expand as soon as the pressure is removed. When enclosed, the molecules are always evenly distributed through the available space, no matter what its size or shape. When another gas is introduced into the same space, it also becomes evenly distributed through it. Compressing the gas, however, develops pressure and the higher the temperature of the gas the greater the pressure will be, since the myriads of rapidly moving molecules constantly beat upon the retaining walls. Liquids are practically incompressible, but gases readily yield to pressure. If the temperature remains the same, doubling the pressure on a gas will cause it to become half its original size, and trebling the pressure will make it one-third its size, and so on. The physicist explains this by the statement that "the volume of a gas varies inversely as the pressure to which it is subjected." At a given temperature and pressure a cubic centimeter of any gas will have the same number of molecules in it.

63. Heat and Compression.—Not only will pressure hinder a liquid from turning to a gas, but if sufficient pressure be applied it may even be caused to turn back to the liquid again. When pressure is applied to a gas, however, a certain amount of heat develops and most gases cannot therefore be

liquefied by pressure alone. A good illustration of the heat that develops when a gas is compressed may be found when air is pumped into a bicycle or automobile tire. After a few strokes of the pump the tube connecting the pump and tire becomes noticeably warmer. When gas under pressure is allowed to expand, however, the molecules at once move further apart and, taking up some of the heat in the process, become cooler. As might be inferred, liquids exposed to gases under pressure absorb much more than they otherwise would. The carbonated water used at soda fountains consists of carbon dioxide forced into the water under pressure.

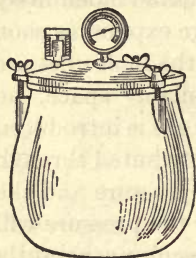


FIG. 23.—Pressure cooker. (Black and Davis.)

64. The Pressure Cooker.—In the *pressure cooker*, which consists of a vessel with a close-fitting cover that allows no steam to escape, advantage is taken of the fact that pressure retards a change of state and causes an increase in the temperature of a substance. The contents of such a cooker may be heated to temperatures of 250°F . or more and thus be quickly cooked. A valve in the cover prevents the pressure from becoming high enough to cause an explosion.

A similar contrivance used in the scientific laboratory is called an *autoclave*. Housewives make use of this principle when they cover the kettle in which food is cooking. In canning, the use of the pressure cooker enables one to preserve many substances that are otherwise very difficult to keep. The great heat to which they are thus subjected kills the germs of decay that are often unharmed by ordinary processes of canning.

65. Refrigeration.—All our mechanical systems of refrigeration are based on the relations of pressure and heat to the change of state. The cooling desired is accomplished by compressing a gas until it becomes liquid and then removing the

heat from it by means of a stream of running water flowing over the pipes in which it is compressed. When the cooled liquid is allowed to expand and become a gas again, it takes the heat necessary for this process from the substances to be cooled. The gas commonly used is ammonia or sulphur dioxide. After the gas has been compressed and cooled, it is allowed to expand into other pipes surrounded by strong brine. The brine thus cooled is pumped away to the place where refrigeration is desired. The gas is used over and over again, the refrigerating system being so arranged that the

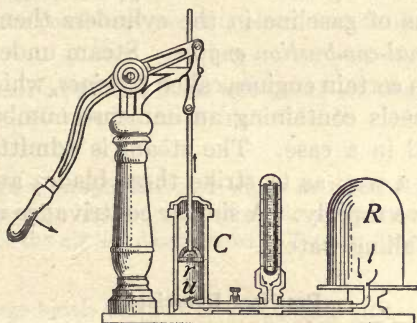


FIG. 24.—The air pump for removing air from the bell-jar *R*. (*Tower, Smith and Turton.*)

pump which compresses it in one set of pipes also serves to remove it from the set of pipes into which it expands. This process also reduces the pressure in the pipes where expansion occurs.

66. Other Uses of Pressure.—The fact that a compressed gas expands instantly when pressure is removed is often taken advantage of in engineering operations. By admitting air under pressure to first one side and then the other of a piston moving in a cylinder, motion is developed which will run drills and riveting machines and do much other useful work. The

brakes on street cars and railway trains are set by compressed air stored in a tank under each car and controlled by the motor-man or engineer. Pneumatic tubes for carrying mail and other light articles are also operated by compressed air. The steam engine derives its power from water vapor under pressure. This, usually called *steam*, is fed into a cylinder at just the right times to give the piston a back and forth motion which is turned into a rotary motion at the driving wheels. The gas engine so familiar from its use in automobiles, pumps and the like, operates in the same way through energy derived from gasoline. Since the pressure in this type of engine is derived from explosions of gasoline in the cylinders themselves, it is called an *internal-combustion engine*. Steam under pressure is also used to run certain engines called *turbines*, which are essentially large wheels containing an immense number of curved blades enclosed in a case. The steam is admitted at many points in such a way as to strike these blades and cause the wheel to revolve rapidly. A similar contrivance makes use of the energy in falling water.

Practical Exercises

1. Fill a florence flask half full of water and heat over the bunsen burner until it boils. Remove from the fire, cork, and invert on some convenient support such as a ring stand. Then pour some cold water on the bottom of the flask. This causes the air within to cool. How does this affect its pressure?
2. How does it affect the boiling point? Why?
3. Why can you not raise the temperature of boiling water in an open vessel to 100°C. in your locality (§104)?
4. Why does it take longer to cook potatoes in Denver than it does in New Orleans?

5. Would the pressure cooker be of any advantage in Denver? Why?
6. When air is allowed to bubble up through a tall cylinder of water, the bubbles get larger as they rise. Why?
7. Explain why a bottle of "charged water" or "soft drinks" overflows as soon as the cork is pulled.
8. At what time of the year is the cork in the ammonia bottle likeliest to pop out?
9. Would it be possible to use air in place of ammonia in refrigeration?
10. Water boils on Mount Blanc at 183°F . At Denver, Colorado, it boils at 203°F . Which place is the higher?
11. Air is often compressed over water in tanks for the purpose of lifting the water to a higher level. Sometimes the system fails to work because most of the air has disappeared. Explain (§63).
12. Fill a large bottle half full of water, cork with a one-hole stopper through which a glass tube extends down into the water. With one breath blow in as much air as possible. Explain what happens (§62).
13. How is the elasticity of the air made use of in automobile and bicycle tires, air cushions, and the like?
14. How is compressed air made use of in the air gun or pop gun?

CHAPTER XII

COMBUSTION AND OXIDATION

67. Activity of Oxygen.—Oxygen is the most active of the chemical elements, and forms compounds with nearly all of them. So great is its affinity for some, that it tears them from other compounds in which they happen to be, and thus causes many substances to break down or disintegrate. Most metals, if left exposed to the air especially in damp surroundings, soon begin to unite with oxygen. Thus iron rusts, and lead and various other metals tarnish. Gold, silver, and platinum do not readily unite with oxygen and thus are in great demand for ornaments and the like. Other metals are often covered with gold or silver to prevent tarnishing (§173). A freshly quarried stone or a newly sawed board soon loses its fresh look and becomes dull by the action of oxygen upon it. Our bodies are kept warm by the slow union of oxygen with the carbon in our tissues, and all ordinary burning is simply a more rapid union of these two elements. It must not be assumed, however, that the union of oxygen and carbon is the only union of this kind that produces great heat. One of the hottest flames known is produced by the union of oxygen and hydrogen and, strangely enough, the result of this union is water.

68. Heat and Light from Oxidation.—Whenever oxygen unites with another substance, the process may be called *oxidation*, though this term is commonly reserved for cases in which the union is not accompanied by the emission of perceptible light or heat, as when iron rusts. When sensible heat and light appear, as in the burning of wood, coal, gas, and oil, we usually call it *combustion*. The only difference, however,

is that one proceeds more rapidly than the other. When metals rust, or wood decays, the total amount of heat developed is the same as if the substance had been burned more rapidly. If plenty of oxygen is available, it may unite with other substances so rapidly as to raise their temperature to a point where they glow, or it may even cause them to change to gases and burst into flame. All flames are burning gases of some kind. A flame, however, does not necessarily produce much light. Light results only when substances are heated very hot or to the condition which is described as *white heat*. The calcium light often used in stereopticons is produced by heating a pencil of lime white-hot in the flame from burning hydrogen. The bright light from the Welsbach gas light is due to the mantle being heated to *incandescence* by the burning gas within it. In ordinary gas jets and in the flame from wood, coal, oil, and the like, the light is due to very hot particles of unburned carbon. When the burning is so managed that all the carbon is oxidized, as in the bunsen burner, very little light results. In pure oxygen glowing charcoal bursts into flame and even iron and other metals burn readily. If it were not for the fact that the oxygen of the air is diluted with four times its volume of nitrogen, building a fire in the stove would probably result in a disastrous conflagration (§105).

69. Kindling Temperature.—In oxidation, as in other chemical reactions, a certain amount of heat is found necessary to induce the change. Most substances will not burn at ordinary temperatures, but must first be heated to their kindling temperature. This temperature is different for different substances. That of anthracite, for instance, is much higher than that of wood. Some substances, such as phosphorus, readily oxidize and burst into flame when exposed to the air at ordinary temperature. In the laboratory, phosphorus has to be kept under water, oil, or similar substances to protect it

from the air. When a substance bursts into flame of its own accord, the process is called *spontaneous combustion*. It occasionally happens that the heat generated by piles of dead leaves, oily rags, damp straw, manure piles, and the like, instead of passing off into the air, accumulates in the material until the kindling temperature is reached, when the material begins to burn by spontaneous combustion. Numerous mysterious fires have been traced to this cause. Spontaneous combustion often occurs in hay-mows, especially if the hay was not thoroughly dried before storing. Even piles of fine coal may take fire in this way. Thorough ventilation does much to avert the danger from such fires.

70. Explosions.—When oxygen unites very rapidly with another substance, especially in a closed space, an *explosion* is the result. Unexpected explosions occurring in valuable material may be most destructive, but when controlled, explosions are sources of much useful power. In general, the more thoroughly the air is mixed with the substance, the greater the explosion is likely to be. Gases, therefore, are more explosive than liquids. If a burning match be thrust into kerosene oil it will be put out, but the gas from kerosene explodes at once if the flame reaches it. Air filled with fine dust from flour, coal, starch, wood, or other substances may cause explosions. In the gas engine, the power is produced by a series of explosions in the cylinders. Gunpowder and other high explosives consist of a mixture of substances which oxidize almost instantly, the oxygen for this purpose being supplied by some of the ingredients in the mixture. By means of the gases produced, projectiles may be fired from guns, buildings and other structures blown up, and rocks torn to pieces (§66).

71. Products of Combustion.—Nearly all combustible materials contain both carbon and hydrogen, and these, uniting with oxygen, produce on the one hand carbon dioxide (CO_2),

and on the other water (H_2O). Hydrogen gas burning by itself produces no carbon dioxide of course. In many cases even when hydrogen is present, carbon only is oxidized and the hydrogen unites with the oxygen in the material to form water. Smoke is not a product of burning. On the contrary, it consists of particles of unburned carbon which, if allowed to escape into the air, is a waste of good material. All fires should be so stoked as to prevent smoke from escaping. When soft coal is burned at home, wetting the coal aids in reducing the smoke. Though ashes are left when coal and wood are burned, these are not products of burning. They simply represent the

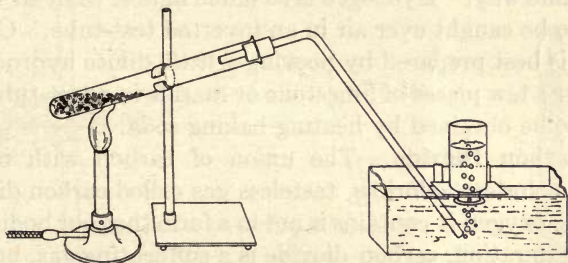


FIG. 25.—A common way of preparing oxygen.

mineral matter which was mixed with the combustible material.

72. Preparing Oxygen and Carbon Dioxide.—There are various simple methods of preparing oxygen for study. A little water added to a few cubic centimeters of sodium peroxide (Na_2O_2) in a bottle or jar will result in the immediate liberation of oxygen. The gas may also be obtained by pouring a small quantity of hydrogen peroxide over a few crystals of potassium permanganate. The customary way of obtaining oxygen is to put about 20 grams of potassium chlorate and an equal amount of manganese dioxide in a large test-tube and heat the mixture over the bunsen burner. The test-tube should be closed with

a one-hole stopper through which the glass tube is thrust. The oxygen given off through this tube, if conducted into a dish of water, may be seen bubbling up through it. By filling the test-tube with water and inverting it in the dish of water over the rising bubbles of gas, they will displace the liquid in the test-tube. Before being removed from the water the test-tube must be closed with the finger or a small sheet of glass to prevent the escape of the gas. If a large bottle or other receptacle be filled with the gas it may also be prevented from escaping by covering the mouth with a sheet of glass. Since all gases are lighter than water, all may be caught over water in the same way. Hydrogen is so much lighter than air that it may also be caught over air in an inverted test-tube. Carbon dioxide is best prepared by pouring a little dilute hydrochloric acid over a few pieces of limestone or marble in a test-tube. It may also be obtained by heating baking soda.

73. Carbon Dioxide.—The union of carbon with oxygen forms a colorless, odorless, tasteless gas called carbon dioxide. Since the oxygen it contains is not in a form that our bodies can use in respiration, carbon dioxide is a suffocating gas, but it is not poisonous as is frequently supposed. It is this gas that gives the sparkle to wine and other effervescent drinks and the pungent taste to soda water. Bread, cake, and the like are made light by bubbles of carbon dioxide in the dough. Although carbon dioxide does not support ordinary combustion, the metal magnesium will burn in it, tearing the oxygen from the carbon for the purpose. When carbon dioxide is mixed with lime-water, it gives the latter a milky appearance, and this liquid is commonly used as a test for the gas. Carbon dioxide is slightly heavier than air and has a tendency to accumulate in the bottom of wells, abandoned mines, caves, and similar places. People are sometimes suffocated by venturing into such places without first testing it for this gas. Since fires will not burn in carbon dioxide, another test for

the gas is a lighted candle. One should not enter caves, wells, or cisterns in which a candle will not burn. Most fire extinguishers are made of substances which liberate a large amount of carbon dioxide when necessary. A common form contains a quantity of baking soda dissolved in water with some means of adding acid when the extinguisher is to be used. The acid combining with the baking soda and water generates so much gas that the pressure forces both gas and water out upon the fire.

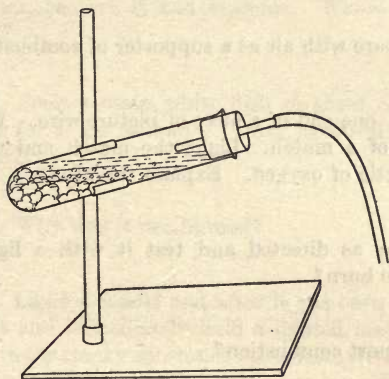


FIG. 26.—Carbon dioxide generated in test-tube with limestone and dilute hydrochloric acid.



FIG. 27.—Bunsen burner.

74. The Bunsen Burner.—One of the most useful pieces of apparatus in the chemical and physical laboratory is the bunsen burner, which is simply a device for securing a hot flame, and is based on the fact that the more thoroughly oxygen is mixed with a combustible substance the more rapidly it will burn. A common form consists of an upright tube connected with the gas supply and having an opening in the base for the admission of air. When the gas is turned on, its passage through the tube draws air in at the base and this, mixing

with the gas, supplies the additional oxygen necessary for complete and rapid burning, and consequently produces great heat.

Practical Exercises

1. Prepare a bottle of oxygen by some of the methods suggested. What color is oxygen?

2. Test the gas with a glowing but not blazing splinter. Will oxygen burn?

3. How does oxygen compare with air as a supporter of combustion?

4. Untwist the strands at one end of a piece of picture wire. Wrap one strand about the head of a match. Light the match and when burning well lower into a bottle of oxygen. Explain the result.

5. Prepare carbon dioxide as directed and test it with a lighted splinter. Will carbon dioxide burn?

6. Will carbon dioxide support combustion?

7. Catch another test-tube of the gas and pour into it about 10 cubic centimeters of lime-water. Shake it well and note the result. This is an infallible test for carbon dioxide.

8. Put about 5 cubic centimeters of lime-water into a clean test-tube and try to pour a test-tube of carbon dioxide into it. Which do you conclude is heavier, carbon dioxide or ordinary air?

9. Light a candle end and place it in the bottom of a clean, dry fruit jar or wide-mouthed bottle. Cover the mouth of the jar with a sheet of glass or cardboard and let it stand for a few minutes. What change takes place in the candle flame. Why?

10. Keeping the jar upright, remove the candle and pour into the jar about 10 cubic centimeters of lime-water. Shake it and note the result. With what substance in the candle has the oxygen of the air united?

11. Place the candle end on the table, light it and hold the mouth of a cold dry bottle over the flame. What soon covers the inside of the bottle?

12. Press a white card down on the candle flame in such a way that the tip of the flame is flattened out against the card. When the card begins to char, remove it and examine. Where was the flame the hottest? Why?

13. Press a clean white dish or sheet of metal down on the candle flame for a few seconds. What chemical element is deposited on the object?

14. Why was it not burned?

15. Light a candle and after it has been burning a few seconds, blow it out and immediately hold a lighted match about an inch above the wick in the smoky substance rising from it. What inference do you make as to whether the burning substance is a solid, a liquid, or a gas?

16. Hydrogen and oxygen unite with much heat to form water. Can you tell why such a flame never smokes?

17. Blow your breath through a straw or glass tube into half a test-tube of lime-water. What chemical substance in the breath does this show?

18. In the process of making wood alcohol, the wood is placed in an air-tight cylinder and heated very hot. When the cylinder is opened the wood, instead of being burned up, is found to have become charcoal. Explain.

19. The filament in certain electric light bulbs is made of carbon. Why is it not consumed when the electricity is turned on?

20. Dissolve a piece of phosphorus, half the size of a pea, in about 3 cubic centimeters of carbon disulphide. (Do not touch the phosphorus with the hands.) Support a piece of blotting paper or filter paper on a ring stand and pour the solution over it. What happens when the liquid evaporates, leaving the phosphorus?

21. What form of combustion is illustrated by the foregoing experiment?

22. Is the kindling temperature of wood higher or lower than the temperature of the school-room?

23. Why do gasoline engines require that a certain amount of air be admitted to the cylinders with the gasoline?

24. Why cannot sodium be preserved under water?

25. Examine the bunsen burner and find the hole at the base for the admission of air. Close this opening, turn on the gas and light it. What color is the flame? Why?

26. Admit air to the burner. What effect has this on the color of the flame? Why?

27. Press a sheet of metal down upon the orange flame for a few seconds. What is deposited on the metal?

28. Make the same experiment with the blue flame. How do you account for the difference.

29. Why does a candle or lamp smoke when not well supplied with air?

30. Large oil lamps and oil heaters have a circular burner with an opening in the center through which air circulates. Of what advantage is this?

31. Why does blowing or fanning a fire make it burn faster?

32. Try heating a glass rod or piece of wire, first in the tip of the blue flame and then in the orange flame. Which is the hotter?

33. Does the hotter flame use more gas? If not, how do you account for the heat?

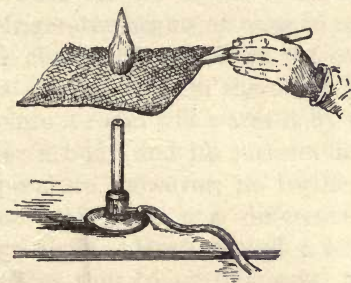


FIG. 28.—Effect of wire gauze on flame. (*Jones.*)

34. All gas ranges are constructed on the principle of the bunsen burner. Examine such a range and locate the opening through which air is admitted to the burner.

35. Should the flame of the gas range be blue, or orange-colored?

36. Light the bunsen burner and press a piece of wire gauze down on the flame. Does the flame pass through the gauze?

37. Place a piece of wire gauze on the bunsen burner in such a way that the gas will rise through it. Turn on and light the gas above the gauze. Then slowly lift the gauze up from the burner. Does the flame pass through the gauze?

38. Explain why it is customary to place a piece of wire gauze under beakers, florence flasks, and the like, when heating them over a bunsen burner.

39. Why does a blanket smother a fire?

40. For putting out a fire in oil, which is better, water or sand? Why?

41. Would flour be of use in putting out an oil fire?

CHAPTER XIII

CONDUCTION AND RADIATION

75. Transference of Heat.—Whenever a body is placed in surroundings cooler or warmer than itself, a transference of heat at once begins, the warmer object giving up its heat to the cooler ones until all are of the same temperature. Ice placed in the refrigerator begins at once to melt, withdrawing the heat for this change of state from the contents of the refrigerator and so cooling it. On the other hand, a hot piece of iron brought into a room will warm it by giving off its surplus heat. After a body and its surroundings have reached a uniform temperature, however, no further transference of heat takes place until some new difference in temperature causes it to begin again. Heat, though a form of energy and not of matter, seems thus to act like water and other liquids, flowing from a higher to a lower level until an exact balance is reached. Such a balance, however, is seldom long undisturbed. The earth daily receives an immense amount of heat upon that part of its surface which is turned toward the sun and as regularly loses it from the parts upon which the sun does not shine. Combustion and oxidation add a share to the change of temperature which matter undergoes, hot and cold winds make new distributions of heat necessary, and various other causes contribute to the almost ceaseless changes that take place in the temperature of matter.

76. Conduction.—One important way in which a body may lose heat to, or absorb heat from, another is by actual contact, as when water is boiled by being placed on a hot stove. The heat, that is, the motion of the molecules, is conducted directly

from the warmer body to the cooler one. Heat also travels readily from molecule to molecule through a substance. A piece of metal left with one end in the fire will soon become hot at the other by *conduction*. Recalling the molecular structure of matter, one easily understands that solids with their molecules close together must in general be the best conductors of heat and gases the poorest. All solids, however, do not conduct heat equally well. The metals, especially silver and copper, are among the best *conductors*, while wood and stone are much poorer.

77. Radiation.—The second way in which the molecular motion of a body may be given to another is by rays sent out from it just as heat rays are sent out from the sun. When we approach the fire, the *radiation* from it makes us aware that it is giving out heat before we actually come into contact with it. As we have discovered, the heat energy radiated from the sun passes unchanged through most transparent substances, and the heat energy from very hot bodies on the earth act in the same way, but the longer heat rays given off by cooler bodies pass more slowly through even transparent substances. The earth receives and loses heat entirely by radiation.

78. Insulators.—Substances which offer resistance to the passage of heat through them are called *insulators*. A poor conductor, therefore, is a good insulator, and *vice versa*. Wood, paper, leather, cotton, wool, feathers, sand, and similar substances make good insulators. Porous materials always make especially good insulators because of the number of small air spaces which they contain. Air is like other gases in being a poor conductor, and, when stationary, as it is in these small spaces, very greatly retards the passage of heat across it. When air can move about, however, it readily carries away heat from a body.

79. Absorption and Reflection.—It has been proved by numerous experiments that the nature of a surface and even

its color has an important bearing upon the rapidity with which it absorbs or radiates heat. A black object usually warms more readily than a lighter one because the latter reflects many of both the light and heat rays, while black objects absorb them and so increase in temperature. It is for this reason that light-colored clothing is worn in summer and dark-colored clothing in winter. Dark soils are usually early soils because they absorb heat so readily in early spring. As might be inferred from the fact that heat, like light, can be reflected, smooth surfaces reflect much heat and warm more slowly than rough surfaces. When a body with a smooth surface is once warmed, however, it cannot radiate its heat as rapidly as a rough one. In general, then, good *reflectors* are poor *radiators* and poor reflectors are good radiators.

80. Distribution of Heat.—All parts of the earth receive the same number of hours of sunlight annually, but this by no means indicates that they are all equally warmed. One reason for the difference in the temperature is the unequal periods of time during which different regions are heated or cooled. In the tropics, there are twelve hours of sunlight and twelve hours of darkness throughout the year. In the Arctic or Antarctic regions, there is a six month's period of daylight and an equal period of darkness annually. In the temperate zone, the length of the day and night varies between these extremes. At mid-summer in the Northern States, the day is about fifteen hours long and the night correspondingly shorter, and in winter these conditions are reversed. This difference in the length of daylight over different parts of the earth is well known to be due to the angle at which the earth's axis is maintained with reference to the sun. In summer it is inclined toward the sun and thus the season of daylight is lengthened. In winter it is turned away and the season of darkness is increased. It is not the length of the period of daylight alone, however, which determines the temperature of

a place. The angle at which the sun's rays are received have an important bearing on the subject. The amount of heat sent us by the sun does not change materially from day to day. When the sun is directly overhead, the heat energy falling on each square centimeter is about $1\frac{1}{2}$ calories a minute, summer or winter. Owing to the shape of the earth, however, and the direction of its axis, that part of its surface outside of the tropics always receives the rays in a more or less slanting direction, and the heat and light are in consequence distributed over a greater area. Nevertheless, at the time of

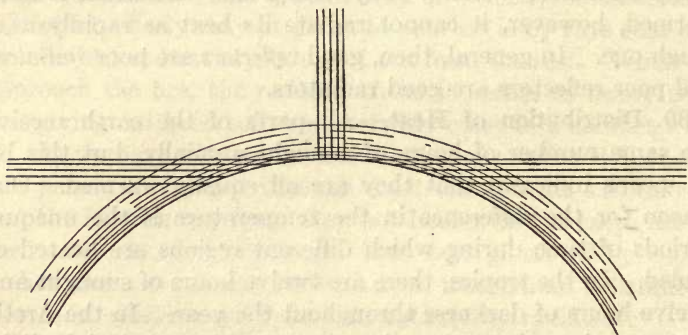


FIG. 29.—Distribution of heat rays at morning and night.

the summer solstice when the longest period of daylight occurs in the Northern Hemisphere, the north pole receives much more heat than the equator. Owing to the evaporation of the ice and snow, however, it is not correspondingly heated. The region of greatest heating at that time is near the latitude of Chicago and Buffalo (§152).

81. The Lag in Temperature.—The longest day in the Northern Hemisphere is in June and the shortest is in December, but June is seldom if ever our hottest month or December the coldest. Moreover, since the sun is more nearly overhead at noon than at any other time, noon should be the hottest part

of the day, and yet this period usually comes one or two hours later. Morning also is likely to be cooler than midnight. The reason for such lags in temperature may be explained by what we know of the phenomena of radiation. When the days are long and the nights are short, as in summer, the period of daily heating is much greater than the period in which the heat can be radiated. Consequently, the earth accumulates heat. In winter we daily radiate more heat than we receive and continue to lose heat until the lengthening days of late winter bring us enough extra heat to balance the daily outgo. The increased temperature after mid-day may be explained in the same way. It is now easy to understand why regions near the equator have a less variable temperature than those near the poles. Their periods of heating and cooling are almost exactly balanced throughout the year.

82. The Effects of Gas and Dust on Radiation.—Dust and smoke in the air intercept the radiation from the earth and act like a blanket to keep in the heat. This explains why the city is warmer than the country during our heated season. The carbon dioxide and water vapor in the air, however, are fully as important in this connection. Though they allow the heat energy from the sun to pass to the earth, they readily absorb the long heat rays and become warm themselves. In fact if it were not for the presence of these two gases in the atmosphere, the earth would lose heat so rapidly at night, even in summer, as to approach dangerously near the freezing point. The variations of temperature in deserts, where the air is dry, are frequently much greater than in places where there is more moisture in the air. Many orchards are now equipped with means for making a smudge to protect the trees from unseasonable frosts. A fog over the orchard may have the same effect.

83. Heat and Living Things.—A certain amount of heat is necessary to the existence of all living things. Since most of their life processes are due to chemical reactions, much of this

heat may come from the organisms themselves. Even plants generate a small amount of heat (§182). Respiration, as we have seen, is really a slow burning which occurs in both animals and plants. The lower animals usually have a temperature not very different from their surroundings, but birds and mammals have a temperature higher than that which ordinarily prevails, and this temperature is maintained nearly uniform whether the surroundings be hot or cold. In health, our own bodies have a temperature of about 98.6°F., and if anything occurs to prevent the loss of the excess heat produced, we soon have a *fever*. The sense by which we judge the temperature of an object is very easily deceived. A piece of iron will feel colder than a piece of wood on a cold morning, but the thermometer proves it to be of the same temperature. On a hot day iron will feel hotter than wood. The explanation of this is that when we are losing heat rapidly we feel chilly, and when we are gaining heat rapidly we feel warm. Metal being a good conductor of heat, therefore, is apparently, but not really, colder or hotter than wood (§ 45).

84. Uses of Radiation and Conduction.—Many familiar operations make use of the principles of radiation and con-

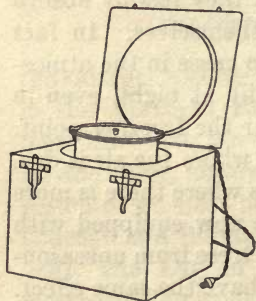


FIG. 30.—A fireless cooker.
(Ahrens, Harley and Burns.)

duction. In the ice cream freezer the material to be frozen is put into a metal vessel surrounded by salt and ice. The metal, being a good conductor, rapidly transfers the heat from the cream to the melting ice. The outside of the freezer is usually made of wood, a poor conductor, which prevents the ice from being melted by the heat from outside. In the *fireless cooker*, the heated food is surrounded by a layer of hay, cork dust, excelsior, or other material in which are many small

spaces containing air. Since heat crosses stationary air very slowly, most of it remains in the food for a long time and so cooks it. If the fireless cooker be first cooled, it will then keep cold foods cold equally well. In this case the stationary air spaces prevent the heat from getting in and warming the food. The *thermos bottles* which so mysteriously retain the temperature of anything put into them, hot or cold, consist of double-walled vessels with a vacuum between the walls. Heat passes through a vacuum even more slowly than it passes through air, and the interior is prevented from either absorbing or radiating heat rapidly. The warm-blooded animals are kept warm in winter by the stationary air in their fur or feathers. When the weather is extremely cold, both birds and mammals are accustomed to fluff up their coats and thus include more air as a greater protection from the cold. The same principle is made use of in winter when we cover the ground about bulbs, half-hardy plants, and newly planted shrubbery, with a *mulch* of leaves, straw, or stable manure. While the mulch does not entirely prevent the earth from freezing, the air spaces it contains protect the specimens from the sudden changes in temperature which are more trying to them than steady cold.

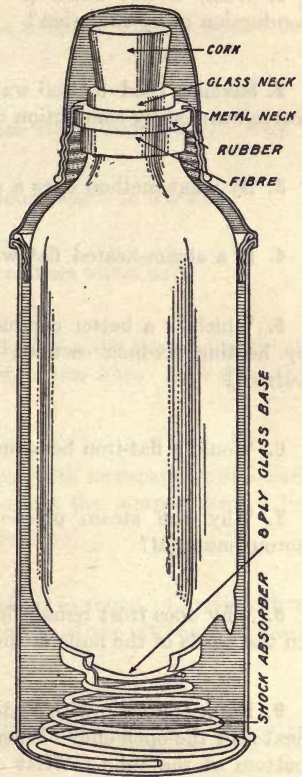


FIG. 31.—Section of a Thermos bottle. (Tower, Smith and Turton.)

Practical Exercises

1. When a hot flat-iron cools in ironing, does it lose its heat by conduction or by radiation?
2. Savages used to boil water by putting hot stones in it. Was the water warmed by conduction or by radiation?
3. By what method does a coal stove warm a room?
4. Is a steam-heated flat warmed by conduction or by radiation?
5. Which is a better conductor of heat, copper or iron? (Find out by heating six-inch sections of copper and iron wire in the bunsen burner.)
6. Would a flat-iron be as useful if made of copper?
7. Why are steam pipes usually covered with asbestos or other porous material?
8. Why does frost remain longer on the boards of a walk than it does on the heads of the nails in the boards?
9. Fill a test-tube with water and by means of a bunsen burner apply heat near the open end. When the water begins to boil there, feel of the bottom of the tube. What do you learn from this experiment as to whether or not liquids are good conductors of heat?
10. Why can one touch a hot iron with a wet finger and not be burned? (Note that the moisture turns to gas.) (§78.)
11. Why will a flask filled with hot water cool off more slowly if wrapped with cotton batting?

12. Why is loosely woven clothing warmer in winter than more closely woven fabrics?

13. Why may loosely woven clothing be cooler in summer than more closely woven fabrics?

14. Which is warmer, close-fitting or loose-fitting underwear? Why?

15. How do double windows keep the house warm in winter?

16. Do we warm our clothes, or do our clothes warm us?

17. Ice-houses and refrigerators have double walls between which is a packing of sawdust, charcoal, cork-dust, or the like. How does this help to keep the ice from melting?

18. Wrapping the ice in the refrigerator with newspaper will retard the melting of the ice. How does this affect the temperature of the refrigerator?

19. Ordinary electric light bulbs have no air in them. Certain others are filled with nitrogen gas. Why do the bulbs of the latter get so much hotter?

20. Why does a crack in the outside of a thermos bottle impair its usefulness?

21. Snow is called "the poor man's manure" because it protects the crops left out over winter from sudden changes of temperature. How does it do this?

22. The outer bark of trees consists of many dead cells containing air. How does this protect the trees from sudden changes in temperature?

23. Which makes a better holder for flat-irons and cooking utensils, a cotton or a woolen cloth? Why?

24. Why are the handles of tea kettles, coffee pots, and the like usually made of wood instead of metal?

25. In which could you heat water more quickly, a tin or a china cup?

26. Frozen mercury thrown into water soon melts, but the water becomes solid. How do you explain this?

27. A kettle of liquid air will boil if set on a cake of ice. Where does it get the heat for this?

28. In canning, why do people often put a silver spoon in the jar before putting in the hot fruit?

29. On which would a kettle of hot water cool more quickly, iron or wood? Why?

30. Should a coffee pot have a smooth or a rough surface? Why?

31. In the air-cooled gas engine, the cylinders have many projections on them. Why?

32. Which should be warmer in the sunshine, a polished shoe or a dusty one?

33. Why do people wear white in summer and black in winter?

34. A black soil is regarded as a warm soil. Why?

35. Which is best for an early garden, a level field or one sloping toward the south? Why?

36. Why does a black object melt into snow or ice faster than a lighter-colored one?

37. In regions where there is much sunlight, water for domestic purposes is sometimes heated by being passed through a coil of pipes exposed to the sun's rays. The pipes are painted black. Why?

38. The pipes mentioned above are usually enclosed in a box with the side toward the sun made of glass. How does this increase its efficiency?

39. Would it be of any use to surround the box with a layer of straw, excelsior or sawdust? Explain.

40. How does spreading cloth or paper over plants protect them from the frosts of early autumn?

41. When dew gathers on plants, how does it prevent further radiation of their heat (§76)?

42. Why does no dew form on cloudy nights? (A lowering of the temperature is necessary for the formation of dew.) (§82.)

43. Why does the floor feel colder to the bare feet than a rug or carpet?

44. The Sahara desert is in the tropics and yet the air there may become so cold at night as to freeze water. Why?

45. Why do we receive less heat and light from the sun at morning and evening than at midday?

46. In winter the sun is some millions of miles nearer the earth than it is in summer and yet it is hotter in summer. Explain.

47. Why is the air in lowlands and valleys likely to be warmer than that on mountain tops?

48. On high mountains, explorers are often badly sunburned though they may suffer from the cold. Explain.

CHAPTER XIV

CONVECTION

85. Convection Currents.—When air is heated, either by conduction or radiation, it expands, becomes less dense, and is pushed upward by the surrounding cooler air near it. This upward current of air is called a *convection current*. It really is but part of a circuit of larger or smaller diameter, for if the current of air rises in one place a similar current must descend in another to take the place of the air that has risen. A *convection circuit* of this kind is always caused by a difference in the temperature of the air. A cake of ice which cools the air and makes it heavier will cause a convection current just as readily as heat will, although in this case the initial movement is downward instead of upward. Convection is sometimes described as a third way in which objects lose heat, but it is very evident that no new principle is involved, and that the heating or cooling of a body exposed to the air movement is primarily due to radiation or conduction. Convection currents may also be caused by variations in the amount of moisture in the air. Moist air is lighter than dry air and of course has a tendency to rise above it.

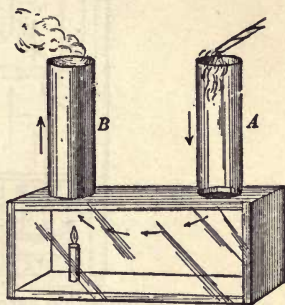


FIG. 32.—Convection current in air. (Black and Davis.)

86. Winds.—Probably the most noticeable convection currents are those which occur as the result of the unequal heating of the air over adjacent regions. When this occurs, a circuit is

set up which may be limited to a portion of a township, a county, or extend over one or more States. The currents which flow along the ground from one region to another are familiarly known as *winds*. Since changes in the position of the air are due to differences in its density, it is easy to realize that the greater the difference between two regions the greater will be the speed of the winds produced. Most interesting illustrations of this may be observed near large bodies of water. During the hours of sunshine, the land warms more rapidly

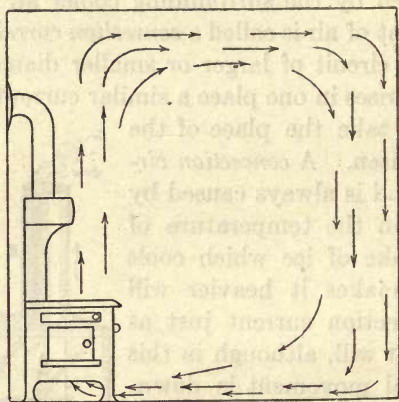


FIG. 33.—Convection currents in a room. (Tower, Smith and Turton.)

than the water, and early in the day the breeze begins to blow inland. At night the land loses heat much more rapidly than the water and soon is cooler. Then the breeze from the land to the water sets in. In regions where the land slopes rapidly toward the water and also receives the direct rays of the sun, the effects are especially noticeable. The winds which blow toward the great storms or *cyclones* that move across the country from west to east at intervals of a few days during most of the year do not blow straight toward the center of the storm area. Owing to the rotation of the earth they

acquire a somewhat circular course and blow around the storm center or *low*. In the northern hemisphere the direction of the winds about a low is the reverse of the direction in which the hands of a clock move, or *counter clockwise*. South of the equator the winds blow *clockwise* about a low. The periods of fair weather between two lows are called *anticyclones*. On a weather map such periods are marked *highs*.

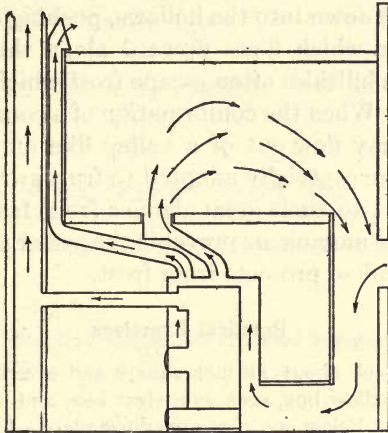


FIG. 34.—Heating and ventilating by means of a hot-air furnace. (Tower, Smith and Turton.)

87. Convection in Liquids.—Though convection currents in liquids may be less noticeable, they are nevertheless as inevitable when a change in density occurs. Proof of this may be seen by filling a florence flask with water and gently heating it after dropping into the flask a few grains of potassium permanganate or other coloring matter to make the currents visible. Our systems of hot-water heating depend upon a convection circuit in which the water is heated in a boiler and, becoming less dense, rises in the pipes to the rooms that are

to be heated. As it gives off its heat its density becomes greater and it finally runs back to the boiler where it is reheated and goes on its rounds again. Probably the greatest convection circuits of which we have any knowledge are such ocean currents as the Gulf Stream and Japan Current which, heated by the sun near the equator, flow away above the colder, heavier water of the ocean and, after giving up their heat to more northern regions, settle down and slowly return to the equator.

88. Convection and Frost.—When the air cools at night, it begins to settle down into the hollows, pushing out the warmer and lighter air which flows upward along the ground. For this reason the hillsides often escape frost which injures plants in the valley. When the conformation of a country is suitable, the cold air may flow out of a valley like an invisible river. Such regions are especially adapted to fruit growing since they are not subject to such great danger from frost. When the wind blows, the moving air prevents the cooler air from settling in one place and so protects from frost.

Practical Exercises

1. Cut two holes about an inch square and several inches apart in the cover of a shallow box, such as a cigar box, and over each hole set a lamp chimney. Below one of the openings place a lighted candle end. Light a piece of touch paper, or anything else that will make considerable smoke, and hold it first over one chimney and then over the other. Account for the direction of the air current in each chimney.

2. Why are refrigerators usually built with the space for ice at the top?

3. Which of our systems of heating makes use of convection currents in the air?

4. Would a hot-air furnace warm the house as well if placed in the attic instead of in the basement? Why?

5. When the sun shines on a section of country, what effect is it likely to have on the movement of the air there?
6. Do you infer that the wind blows from a single direction or from all directions toward a column of rising air?
7. When the wind blows from the north, in what direction is the nearest column of rising air?
8. Where is it when the wind blows from the east?
9. How do you explain the statement that the Gulf States help to warm Chicago?
10. On a weather map the areas marked "High" are regions of heavy air and those marked "Low" are regions of lighter air. In what direction should the air near the ground move, from a high to the nearest low or the reverse?
11. In what direction should the elevated currents connecting a high and a low flow?
12. Why does blowing a hot liquid cool it?
13. On a cold day, why does it seem so much colder in the wind than in a sheltered situation (§83)?
14. How does an open fireplace ventilate a room?
15. Which would be more effective in ventilating a room, opening a window at the top *or* bottom, or opening it at the top *and* bottom? Why?
16. Why does not the carbon dioxide produced by a flame extinguish it?

17. How does the chimney keep a lamp from smoking?

18. In a hot-water heating system which pipes do you infer are lower, those which carry the water from the heater or those which bring it back? Why?

19. The bottom of the ocean, even in the tropics, is known to have a temperature only a few degrees above freezing. How do you account for this?

20. In what general direction do you infer the water moves at the bottom of the ocean?

21. When a fire is lighted out of doors, why do the sparks fly upward as soon as it is burning well?

22. Why do factories which burn coal secure a better draught by the use of tall chimneys?

23. When the fire is first lighted the stove may smoke. Why?

CHAPTER XV

EVAPORATION

89. Conditions Affecting Evaporation.—Evaporation is the name given to that change of state in which a liquid assumes the gaseous form. Liquids will evaporate at any temperature but, since heat is always absorbed in the process, the warmer the substance is made the faster will evaporation take place. When a substance evaporates without the special application of heat we assume that the heat necessary is derived from surrounding objects, and this proves to be the case, for evaporating liquids are always somewhat cooler than their surroundings. The heat thus absorbed becomes latent; that is, it is used up in the change of state and does not raise the temperature of the liquid. Other things being equal, the greater the surface exposed, the more rapid will be the evaporation. In sugar making, the syrup to be evaporated is placed in large shallow pans to facilitate the process. Evaporation is also promoted by removing the vapor as fast as it is produced and thus clearing the way for other molecules of the evaporating liquid to fly off. There is, as might be expected, a considerable difference in the rate at which different liquids evaporate, but all are alike in requiring heat for the process. Liquids which evaporate rapidly of course take up heat rapidly and feel colder than those which evaporate more slowly. If a liquid disappears very quickly when exposed to the air, it is said to be *volatile*. Sublimation, already mentioned (§52), may be considered as a form of evaporation which takes place in some solids at a temperature lower than their melting or

boiling points. On a cold day, ice will sublime, and a light snow fall may thus disappear without making the ground wet. Frost frequently sublimates instead of melting. Other substances are known which, owing to their readiness to unite with oxygen, cannot be turned to gases under ordinary conditions. When heated beyond a certain point they do not even become liquid but form gaseous compounds with the oxygen in the air. Carbon and phosphorus are elements of this kind.

90. Boiling.—If the temperature of an evaporating liquid be increased sufficiently, the surface will not provide enough space for the escape of all the vapor produced. In consequence, bubbles of the vapor begin to form within the body of the liquid itself at the point where the heat is being applied. When the temperature is sufficiently high to cause these bubbles to rise to the surface and escape into the air, we speak of the process as *boiling*. For some time before boiling begins, the bubbles of vapor may rise into the cooler parts of the liquid and there be condensed to liquid again. This condition is called *simmering*. In a liquid exposed to the air, boiling can occur only when the average speed of its molecules exceeds the speed of the molecules of the air, otherwise they will be knocked back into the liquid again by collision with the air molecules. This explains why compressing the air over a boiling liquid increases the boiling point. The molecules of air pushed closer together and moving at higher speeds make the escape of the molecules of the liquid more difficult (§61). If the pressure be reduced, however, the molecules escape at a much lower temperature. Water evaporates into a vacuum almost instantly. If the air did not hinder evaporation, we would be living in an atmosphere saturated with moisture. Though the pressure of a gas over a liquid may retard the evaporation into it, it does not permanently prevent it. As much water will eventually evaporate into an air-filled space as would evaporate into it if the air were not there.

91. Gases and Vapors.—There is no real difference between gas and vapor. As commonly regarded, vapors will condense or become liquid again at ordinary temperatures while gases will not. Thus steam would be called a vapor but air would be called a gas. Water vapor, however, is as much a gas as is the oxygen or nitrogen of the air. Gaseous water (steam or water vapor) is invisible. What is commonly called steam consists of fine particles of liquid water. By examining the substance issuing from the spout of a rapidly boiling kettle, one will note a clear region between the spout and the visible matter coming from it. This invisible portion, only, is steam. Though gaseous water is invisible, many other gases are not. Chlorine gas has a greenish hue, iodine gas is violet, and bromine gas is brown.

92. Uses of Evaporation.—Since water in turning from a liquid to a gas takes up 536 calories of heat for each gram concerned (§59), its evaporation may be made the means of very effective cooling. We sprinkle the lawn or street in summer to cool the air, but the mere presence of the water does not much affect this. Some heat, to be sure, is absorbed in bringing the water to the temperature of its surroundings, but it is the great amount of heat absorbed as it evaporates that produces most of the cooling. On a moist or “muggy” day in summer, we realize very clearly that evaporation is a cooling process. On such days, owing to the amount of moisture in the air, the perspiration does not readily evaporate and thus fails to cool our bodies. If the air is dry, much warmer days may be less oppressive, owing to the rapid evaporation of the perspiration. It is this evaporation of the perspiration that regulates the temperature of the body, keeping it at practically the same temperature throughout the year. In summer the increased heat causes us to perspire more, but even in winter some moisture is given off in this way, as may be easily seen by touching a cold piece of metal or sheet of glass with the finger tips for a short

time. The mist or the insensible perspiration will soon be deposited on the object. The danger of remaining in wet clothing is due to the fact that the evaporation of the moisture takes a great amount of heat out of the body and so chills it. If one happens to be exercising vigorously and thus producing considerable amounts of heat, he is not likely to become chilled in wet clothing. If one happens to get wet, therefore, the best way to avoid a cold is to keep moving. In the absence of ice, housewives often contrive to keep milk from souring by cooling it through evaporation. The vessel containing the milk is wrapped in a cloth which is allowed to dip into a dish of water. The moisture rises in the cloth and evaporates, taking the heat out of the milk for the purpose. A great deal of the water taken up by plants is evaporated from the leaves and other parts, thus keeping them cool, as our perspiration keeps us cool.

Practical Exercises

1. Put a drop of water, a drop of alcohol, and a drop of ether on the back of your hand and note which evaporates first. Which feels coldest? Why?

2. Where does a fog go when it disappears?

3. When fog disappears does it warm or cool the air (§68)?

4. Of what advantage is it to give people alcohol baths when they have a fever?

5. How does hanging wet cloths in a room cool it?

6. Why are wet soils likely to be cold for a long time in spring?

7. Why is it cooler on land in a wet bathing suit than in the water?

8. All rivers run to the sea and yet the sea is never quite full. Why?
9. In tropical countries, drinking water is kept cool by being placed in porous earthenware jars through the walls of which part of the water escapes and evaporates. How does this keep the rest of the water cool?
10. Which would register higher, a thermometer with its bulb covered with a wet cloth or one with its bulb dry? Why?
11. How would much moisture in the air affect the height of a wet-bulb thermometer?
12. Housekeepers find that water "boils away" faster on some days than on others. How do you account for this?
13. Put a crystal of iodine into a test-tube and heat gently over the bunsen burner. What is the result (§52)?
14. Account for the fact that when a piece of camphor gum is exposed to the air, its odor may soon be noticed at some distance from the substance.
15. Explain how wet cloths hung out on a cold day may "freeze dry;" that is, may freeze and then dry.
16. How does fanning cool us when we are warm?
17. Why does a baked potato weigh less than it did when raw?
18. Why do clothes dry most rapidly on a windy day?
19. Why do strong winds rapidly dry the soil?
20. When there is no perceptible movement of the air, one can often discover which way it is moving by wetting the finger and holding it up in the air. Explain.

CHAPTER XVI

MOISTURE IN THE AIR

93. Variation in Amount.—The air always contains some moisture but the amount depends upon a variety of conditions. It is greatest, of course, in the vicinity of large bodies of water and least in deserts, but in any locality it may vary from day to day, being affected by the prevailing winds, the amount of sunshine, the elevation above sea level, and the temperature. If we place a quantity of water in a bottle, and leave it uncorked, it will soon escape into the air, but if the bottle be corked, the limit to the evaporation is soon reached and the rest of the water remains in the bottom of the bottle. From this we discover that water cannot continue to evaporate into a given space for an indefinite period. As soon as a space has a certain amount of water vapor in it, no more can be taken up and we say that it is *saturated*. If the temperature of the space is then raised, its capacity for moisture is increased and more will evaporate into it, but if the temperature be lowered, its capacity is diminished and some of the moisture must be dropped. The temperature point at which the water vapor in a given space begins to turn back to liquid water when the temperature is lowered is called the *dew-point*. The dew-point is not a fixed point like the freezing and boiling points, but varies from day to day or from hour to hour, according to the amount of moisture in the space and its temperature. When the temperature is high and the space nearly saturated, a very slight drop in the temperature will cause some of the moisture to *condense* and return to the liquid state. If there is very little moisture in the given space, however, the

temperature may drop many degrees without the dew-point being reached.

WEIGHT IN GRAINS OF WATER VAPOR PER CUBIC FOOT AT
SATURATION

Temp. F.	Grains	Temp. F.	Grains
0	0.481	55	4.849
5	0.610	60	5.745
10	0.776	65	6.782
15	0.986	70	7.980
20	1.235	75	9.356
25	1.551	80	10.934
30	1.935	85	12.736
35	2.366	90	14.790
40	2.849	95	17.124
45	3.414	100	19.812
50	4.076		

94. Humidity.—The amount of moisture actually present in a given quantity of air at any time is called its *absolute humidity*. The absolute humidity is usually expressed in grains of water vapor per cubic foot. The ratio of the absolute humidity in a given space at a given temperature to the amount of moisture the space could hold if saturated gives its *relative humidity*. When the temperature of the air is lowered it does not affect the absolute humidity provided the dew-point is not reached, for the mere lowering of the temperature cannot affect the amount of moisture actually present, but since the relative humidity is the ratio of the amount present to the amount the space could hold if saturated, lowering the temperature increases the relative humidity and raising the temperature decreases it. To be called moist, the air should have more than 50 per cent. of the vapor it is capable of holding. The amount of moisture in the air over cultivated land areas is between 50 and 60 per cent., and over water, of course, it is much greater. The relative humidity of our dwellings and

school-rooms, therefore, should be at least 50 per cent. Some interesting phases of humidity are encountered when dwellings are heated by furnaces. When the air is taken in from outdoors, as it commonly is, the heat of the fire causes it to greatly increase in volume, but the moisture it contains is not increased in amount and there is therefore much less per cubic foot than in the outside air. To remedy this, moisture is usually added to the air by evaporating water into it. Even when such means are used the air in our dwellings is seldom moist enough.

Not only do we feel warmer in moist air above a certain temperature, but the membranes of the throat and other respiratory passages are kept in better condition and thus colds and sore throats are avoided.

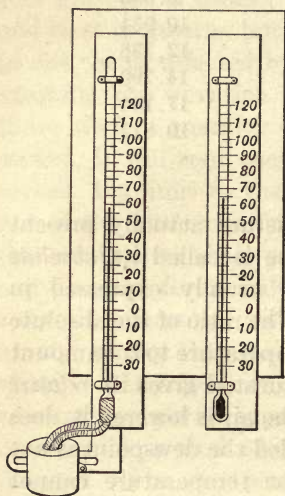


FIG. 35.—Wet- and dry-bulb thermometers. (Duff.)

95. The Hygrometer.—A device for measuring the moisture in the air is called a *hygrometer*. One of the simplest, called the *hair hygrometer*, is made of a single long hair from which all oil has been removed by soaking it in ether. When exposed to moist air this absorbs moisture and contracts, and when it dries, it lengthens again. If passed over a tiny pulley and kept taut by a small weight, its shortening and lengthening

may be made to move a hand on the pulley and so indicate the relative amount of moisture in the air. The instrument most frequently used is called a *psychrometer*. It consists of two thermometers that read exactly alike mounted together. One thermometer is so arranged that its bulb may be kept wet. As the moisture evaporates, the temperature of this thermometer is lowered, and if the air is dry, the evaporation

will of course be rapid and the temperature registered will be much lower than if the air were moist. The second thermometer registers the true temperature of the air, and a comparison of the temperatures registered by the two thermometers will indicate the relative humidity.

96. Forms of Condensation.—Rain, snow, hail, fog, clouds, dew, and frost are some of the different forms which result from a lowering of the temperature of the air below the dew point. *Fog* and *clouds* consist of tiny particles of liquid water condensed from the water vapor in the air. The only difference between them is that one is near the ground and the other at a considerable altitude above it. On a mountain top a cloud which drifts across it is found to be only a heavy fog. Clouds or fogs always occur when the temperature of the air falls below its saturation point. A certain amount of dust in the air seems necessary for the formation of clouds, each particle of dust forming a nucleus upon which moisture can condense. When single clouds are formed in the sky, each is at the top of a column of moist air which has risen high enough to be condensed. Other clouds may be formed by moist winds blowing into colder regions and their moisture being condensed. *Rain* occurs when the particles in the cloud become so large from further condensation that they no longer float in the air. If the raindrops fall into layers of warmer air, they may be again evaporated without reaching the earth. Over very hot regions, such rain storms far above the earth are occasionally observed. *Dew* is the moisture in the air condensed on objects on or near the ground. It is incorrect to assume, however, that all the moisture found on grass and other herbage in the early morning is dew. A great deal of it is moisture given off by the plants themselves in the form of liquid water. Rain and dew occur only when the dew-point is above the freezing point. When the dew-point is lower than the freezing point, *hail*, *snow*, or *frost* results when condensation occurs. It may be

noted that this latter phase of condensation is a form of sublimation.

97. Cloud Forms.—A considerable number of cloud forms have been distinguished and named, the principal ones being easily recognized. Highest of all are certain thin wisps of cloud commonly called “mares’ tails” and known to the meteorologists as *cirrus* clouds. They may be nearly ten miles above the earth and are supposed to consist of small ice crystals. The *cirro-cumulus* clouds produce the familiar “mackerel sky.” They are in the form of short, often curved, sections and are nearly as high in the air as the *cirrus* clouds. *Cumulus* clouds are the fleecy day clouds which appear like great piles of wool in the sky. They are much nearer the earth—seldom more than a mile high. *Cumulus* clouds may continue to enlarge until they form the *cumulo-nimbus* clouds called “thunder heads” which produce most of our thunder storms. The *nimbus* cloud, found at an altitude of less than a mile, is the ordinary rain cloud which produces the all-day rains. Lowest of all are the *stratus* clouds—flat, level clouds of no distinct form, seen most frequently in the early part of the day. They are seldom more than half a mile high, and usually disappear as the day advances. Fog may be called a *stratus* cloud near the ground.

Practical Exercises

1. Into a metal cup or can with a brightly polished outer surface put a quantity of cold water. Then drop pieces of ice into the water stirring it with a thermometer until a film of moisture begins to appear on the outside of the vessel. The reading of the thermometer at this instant will give the approximate temperature of the dew-point in the place where the experiment is made. What was the temperature of the dew-point in your experiment?

2. Account for the formation of frost on window panes in cold weather (§93).

3. Why does no frost form on the outside of window panes in cold weather?

4. How can you tell, by consulting the wet- and dry-bulb thermometers, whether the dew-point at the time is high or low?

5. Examine the wet- and dry-bulb thermometers in your school and see if the relative humidity is sufficiently high. If the school has no wet-bulb thermometer one can easily be made from an ordinary thermometer.

6. Why is it incorrect to say that dew falls?

7. If the dew-point is above 40°F . on autumn evenings no frost is expected. How does the formation of dew prevent frost?

8. When you notice single clouds near the horizon on a warm day you find that the under side is nearly level. How do you account for this?

9. Explain how high mountains prevent moisture-bearing winds from carrying moisture beyond them (§§63, 93).

10. From a geography, select and name a desert that is due to the cause mentioned in question 9.

11. Clouds, being composed of particles of liquid water, are heavier than air. Why then do they not descend to the earth?

12. If a wind moves from a cold region into a warmer one, will its capacity for moisture be increased or diminished?

13. Will it be likely to bring clear or cloudy weather? Why?

14. What wind ought to bring clouds in your region?

15. What wind blows before a storm in your region?
16. Why are summer thunder storms most likely to occur after the sun has begun to go down?
17. Why is it foggy in the North Atlantic in the vicinity of icebergs?
18. Explain the "banner cloud" that often streams away from a mountain top opposite the side from which the wind is blowing.

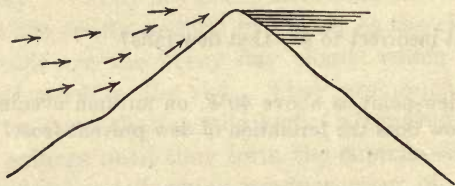


FIG. 36.—Banner-cloud diagram.

19. Why does little rain fall in the Sahara Desert when moist winds from the Mediterranean Sea often blow over it?
20. Why can you "see your breath" on a cold day?
21. Why is fog more frequent in river valleys and along large bodies of water than elsewhere?
22. Explain the formation of the cloud which sometimes appears over a burning building.
23. Why is fog more likely to form near cities than in the country?

CHAPTER XVII

CAPILLARITY AND OSMOSIS

98. Water Surfaces.—A liquid is said to have its free surface level, but this does not mean that it would conform to a straight line. Since the earth is a sphere, the water level must constantly curve. This curvature may easily be seen on a long straight stretch of water such as a lake or canal. If a telescope or field glass is fixed exactly horizontal at a certain distance above the water and a target a mile or so away is placed at the same height above the water, it cannot be seen through the glass, owing to the curvature. A water surface is considered level, however, when it conforms to the curvature of the earth. A well-known proverb runs to the effect that “water seeks its level.” We find this true no matter what the shape of the vessel containing it happens to be. If vessels of various shapes

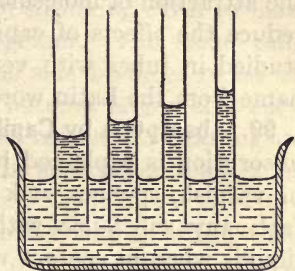


FIG. 37.—Capillary attraction in tubes. (*Tower, Smith and Turton.*)

and sizes are connected at the bottom in such a way that liquid is free to move from one to the other, pouring water into any of the vessels will cause it to rise to the same height in all of them. There are certain conditions, however, in which water is not exactly level, even in ordinary vessels. If we stand a sheet of glass on edge in a dish of water for instance, and examine the point at which the surface of the water comes into contact with it, we find that it curves upward here. The

same thing occurs when a glass is partly filled with water. The surface slopes upward wherever it is in contact with the glass. If mercury instead of water is used, the surface curves downward instead of upward. Experiments with various liquids have shown that whenever a liquid wets or clings to the walls of the vessel in which it is contained, the curvature is upward, and when it does not wet the surface, the curvature is downward. The phenomenon is best shown by means of small glass tubes of different sizes. When several of these are stood in the same dish of water, the liquid always rises highest in the smallest tubes. In mercury, the surface is depressed, the greatest depression occurring in the smallest tubes. The water rises in the tubes because of a certain attraction between it and the tubes, which is known as *capillarity*. Heat, which lessens the attraction of molecules for one another, has a tendency to reduce the effects of capillarity. The phenomena were first studied in tubes with very fine hair-like openings, hence the name from the Latin word *capillus*, meaning a hair.

99. Absorption by Capillarity.—A great deal of what we call absorption is explained by capillarity. Wood takes up glue or varnish, sponges soak up water, blotters take up ink—in fact, any substance with small openings in it will absorb liquids when in contact with them. If one end of a towel is left in a dish of water, the water will creep up in the capillary spaces in the towel and soon leave the dish empty. Most of the moisture used by plants moves through the soil by capillarity. It is by this means that plants obtain moisture at some distance from their roots. When the moisture in the soil close to the roots has been taken up, more moves in by capillarity.

100. Deliquescence.—Some crystalline substances have such an affinity for moisture that they rapidly absorb it from the air and are thus dissolved. A piece of sodium hydroxide liquefies in a few minutes if exposed to the air and must be

kept in moisture-proof receptacles. Sulphuric acid rapidly gains in weight by absorbing moisture from the air, and quicklime slacks in the same way. When a substance thus dissolves it is said to *deliquesce* or to be *deliquescent*. If it only takes on additional moisture, it is said to be *hygroscopic*. Most mosses and lichens are hygroscopic. The lichens, especially, get much of the moisture used in their life processes from the moisture in the air. There are also certain crystalline substances which act in a manner exactly opposed to deliquescence when exposed to the air. Instead of taking on more moisture they give up what they have and fall into a fine powder. Such substances are said to be *efflorescent*.

101. Shrinking and Warping.—Many vegetable and animal fibers have the property of becoming shorter and thicker when wet. This is taken advantage of in shrinking cloth to make the threads thicker and closer together. The same thing happens when boards warp. If one side becomes moist the swelling fibers cause that side to become larger and curve toward the dry side. One of the chief reasons for painting and varnishing woodwork is to prevent the absorption of water and the consequent warping.

102. Osmosis.—There is still another way in which water moves in substances against the force of gravity. If two liquids of different density, that ordinarily mix, be separated by a membrane such as parchment paper, hog's bladder, or the cell walls of animals or plants, they usually begin to flow through the separating membrane and continue to do so until the liquids on each side of it have the same density. This is known as *osmosis*. The liquid of less density will, of course, go through the membrane more rapidly than the denser liquid and for a time may increase the bulk of the latter very considerably, but as the density of the two liquids becomes more nearly uniform, the level of the liquids becomes the same. An interesting illustration of osmosis may be had by filling a this-

tle-tube half full of molasses, tying a piece of parchment paper or other membrane over the open end, and inverting it in a jar of clear water. The water at once begins to flow into the thistle-tube through the membrane, and often increases the bulk of the molasses so much that it will rise in the stem of the thistle-tube 18 or 20 feet against gravity. As the molasses slowly diffuses out into the water, the density of the two liquids

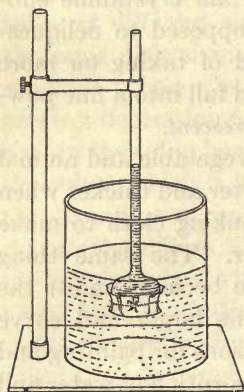


FIG. 38.—Method of setting up osmosis experiment.

gradually becomes the same and the column of liquid falls. Gases separated by a membrane behave in the same way, but the phenomena are most noticeable in liquids. To certain kinds of liquids and gases, membranes may be semi-permeable; that is, they may allow fluids to pass but retain substances dissolved in them. The cell walls of plants with their lining of protoplasm act in this way, and while permitting the inflow of water and food materials, refuse to allow the matter within the cells to escape.

Practical Exercises

1. Fasten two strips of glass together in narrow V-shape using a small piece of wood to keep the V open. Stand the strips on edge in a dish of water and explain the behavior of the liquid.

2. Account for the fact that if you touch one corner of a lump of sugar to a liquid, such as coffee, the liquid will spread through the entire lump.

3. What use is made of capillarity in the wicks of oil lamps?

4. Why is writing paper "sized" while blotting paper is not?

5. How does the split in the pen make the ink flow more uniformly?
6. From which would you expect more water to evaporate, a compact or a loose soil, both being equally wet? Why?
7. In which would you expect the soil water to rise higher, a sandy or a clay soil? Why?
8. How would a mulch of straw, leaves, or even dry earth, prevent the moisture in the soil from escaping?
9. In planting small seeds, it is customary to firm the soil over them to keep them moist. How does firming the soil accomplish this?
10. Why is salt likely to become lumpy in wet weather?
11. When moss is soft to the tread, it is regarded as a sign of an approaching storm. Why?
12. When clothes are sprinkled for ironing, why are they usually rolled up and allowed to lie for a short time?
13. Why do doors, drawers, and windows often stick in wet weather?
14. In old houses, the floors and stairways often snap and creak before a change in the weather. Explain.
15. In quarries, pieces of rock are sometimes broken off by the simple expedient of drilling several holes in a row where the break is desired, fitting each hole with a plug of dry wood and then wetting the plugs. Explain.
16. Why may a wooden tub or barrel fall to pieces if not kept moist?

17. When raisins or other dried fruits are thrown into water they increase in size. Explain.

18. If sugar be sprinkled over berries or other juicy fruits, a quantity of juice soon appears in the dish. Account for this.

19. When fresh fruits are put into thick syrup in preserving, the fruit soon shrivels. Why?

20. How does putting salt on grass kill it?

21. The crispness of celery, lettuce and other vegetables is increased by putting them in fresh water. Explain.

22. In making extracts the druggist cuts the substance he is working with into small bits, covers them with alcohol or water and lets them stand for a time. How does this extract the matter desired?

23. Should meat intended for a stew be rapidly or slowly cooked?

24. Will salting the water in which a piece of meat is stewing, help or hinder the extraction of its flavor?

25. Account for the flow of sap from trees when injured in spring.

CHAPTER XVIII

PRESSURE OF THE AIR

103. The Atmosphere.—The gaseous matter which envelops the earth and penetrates some distance below the surface is called the *atmosphere*. We commonly speak of it as the *air*. Air consists almost entirely of two gases, oxygen and nitrogen, which occur as a mechanical mixture and not as a chemical compound. Of this mixture, oxygen forms about 21 per cent. and nitrogen about 77 per cent. There are also present in the air, carbon dioxide, water vapor, traces of argon and other rare gases, ammonia, dust, and the spores of plants. In addition to the oxygen and nitrogen, the only constituents worth notice at this time are carbon dioxide and water vapor. Carbon dioxide, though a product of all ordinary burning, forms only about $\frac{3}{100}$ of 1 per cent.; that is, only three parts in 10,000 of dry air. Water vapor varies in amount as we have already seen, and is usually present in much larger quantities, often as much as 3 per cent. Since the amount of water vapor present depends upon the time and locality, it need not be considered at this point. In ten thousand parts of average air, therefore, the chief components are represented about as follows:

Nitrogen.....	7,700 parts
Oxygen.....	2,100 parts
Argon.....	100 parts
Carbon dioxide.....	3 parts

104. Weight of the Air.—Though extremely light in comparison with other familiar substances, air, being a form of

matter, has weight. At sea level, a cubic foot of air weighs about an ounce and a quarter. The total weight of the atmosphere is some 5,000,000,000,000,000 tons. A column of air an inch square, extending from sea level upward as far as the air goes, weighs nearly 15 pounds; that is, it presses downward or, rather, is pulled downward by gravity, with a force of nearly 15 pounds to the square inch. Since air, like other gases, is easily compressed, the air at sea level is densest, owing to the pressure of other air above it, but this density and pressure grows steadily less as we go upward. The pressure of the air at sea level is often taken as a standard for measuring other pressures, and is spoken of as the *pressure of one atmosphere*.

105. Function of the Air Constituents.—Oxygen is the life-giving principle of the air, for without it neither animals nor plants could exist. Its union with carbon in our bodies keeps us warm, and similar unions elsewhere supply most of the energy used in the world. Though oxygen is of such great importance, it would be harmful if it occurred in greater amounts, since combustion or oxidation would go on altogether too fast. A cook-stove would burn up in pure oxygen. The most important use of nitrogen, so far as man is concerned, is to dilute the oxygen and thus put a damper on its activities. It is the nitrogen which gives the air most of its weight and pressure, and makes it possible for it to turn windmills, move sailboats, and the like. In tornadoes, the air may move at such a high speed as to uproot trees, destroy buildings, and do many curious things, such as driving straws through boards. The pressure of rapidly moving air also makes heavier-than-air flying machines possible. So long as they are passing rapidly through the air, the pressure is sufficient to keep them up. Carbon dioxide, in addition to being the material from which the bulk of the solid parts of plants is made, also absorbs much of the heat radiated from the earth, and together with

water vapor and dust, acts as a blanket to keep in the heat and prevent sudden changes in the temperature of the air.

106. The Barometer.—Owing to various causes, the pressure of the air in a given locality varies from day to day. The most important of these causes are differences in the temperature of the air and varying amounts of water vapor in it. Moist air is lighter than dry air, and warm air lighter than cold. Variations in air pressure are measured by the *barometer*. This instrument consists of a glass tube closed at the upper end, and filled with mercury. The lower end of the tube dips into a dish of mercury and the pressure of the air on the surface of the dish causes the mercury in the barometer tube to rise and fall with each variation in pressure. A scale is attached to the upper end of the tube by means of which the variations may be ascertained. A sliding indicator and scale called a *vernier* is attached to the tube for exact measurements. At sea level the pressure of the air is sufficient to support a column of mercury 760 millimeters or 30 inches long. With each rise of 90 feet above sea level the mercury lowers about $\frac{1}{10}$ inch. The daily fluctuations of the barometer seldom vary more than a few tenths of an inch. This, however, represents a considerable difference in pressure. A difference of one inch in barometer readings indicates a difference of more than a million tons over a square mile. Although mercury is the most satisfactory fluid for use in barometers, any other liquid might serve to indicate pressure, but in case a lighter



FIG. 39.—
A standard
barometer.
(Tower, Smith
and Turton.)

liquid, such as water or alcohol were used, the tube would have to be very much longer in order to accommodate an equal

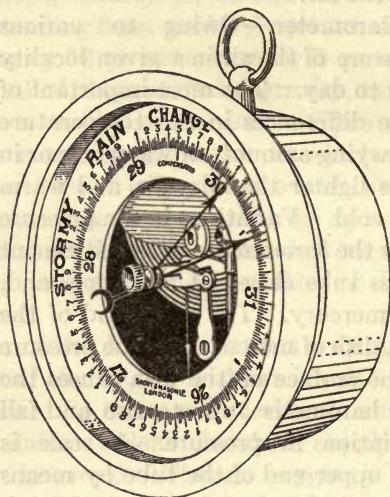


FIG. 40.—An aneroid barometer. (Tower, Smith and Turton.)

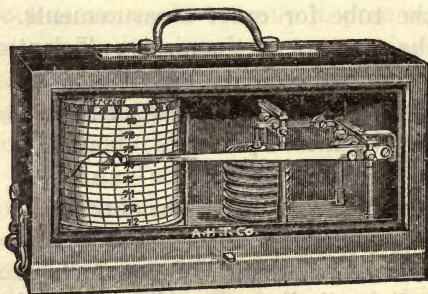


FIG. 41.—The barograph.

weight of the liquid. The *aneroid barometer* is a more portable instrument for measuring pressure. It consists of a thin-walled, air-tight flat metal box, with a thin corrugated top, from which

some of the air has been removed. As the atmospheric pressure varies, the top of the box rises or falls, and this motion is communicated by a spring and levers to a hand moving over a scale, which indicates the pressure. Since this style of barometer is easily carried about, it is frequently used in estimating the height of mountains, etc. The *barograph* is essentially an aneroid barometer with an indicator adapted to making a continuous record on a moving strip of paper.

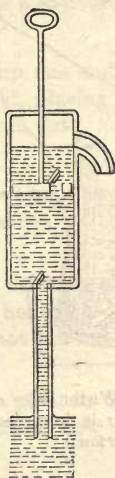


FIG. 42.—Lift pump. (Duff.)

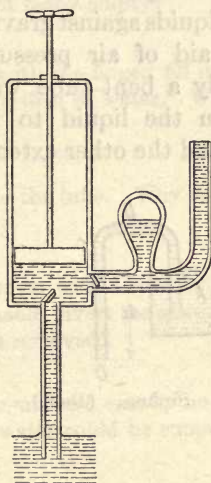


FIG. 43.—Force pump. (Duff.)

107. Lift Pumps and Siphons.—The ordinary *lift pump* for raising water and other liquids above their natural level, makes use of the pressure of the air. The pump has a plunger and valves by means of which the air is removed from the pipe extending down into the liquid, and the pressure of the air then forces the liquid to rise in the pipe. Liquids will not rise to any height, however, for the air only presses upward with a force of about 15 pounds to the square inch. At sea level,

this is only sufficient to force water up to a height of about 34 feet. The pumps which raise water to much greater heights are called *force pumps*. In such pumps, the upward stroke of the piston causes more water to rise in the pipe, and the downward stroke closes the valve and forces the water to flow through another pipe to higher levels. Even in this type of pump, the valves and plunger must be located near enough to the surface of the liquid to take advantage of the air pressure. A *siphon* is a device for lifting liquids against gravity with the aid of air pressure. It is simply a bent tube with one end in the liquid to be siphoned and the other extend-

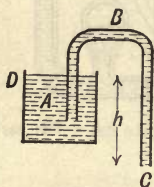


FIG. 44.—Siphon. (Duff.)

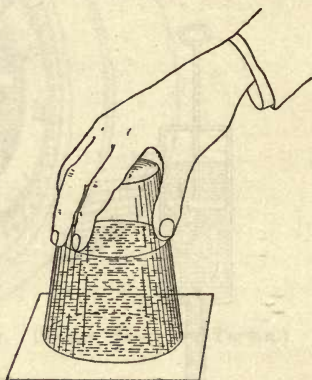


FIG. 45.—Water does not run out when tumbler is inverted. (Tower, Smith and Turton.)

ing outside to a lower level. When the air is removed from the tube, either by pumping it out or by filling the tube with the liquid, the liquid in the vessel will run out, though it may have to rise a considerable distance to do it. The air pressure on each end of the tube is, of course, practically the same, but since the outer end of the siphon is always longer and lower, it contains a greater weight of water which, beginning to run out, tends to form a vacuum at the bend, but this is immediately filled by more water which is pushed up by the air pressure over the liquid in the vessel, and so the siphon con-

tinues to run. Siphons are used in emptying tubs, barrels, cisterns, and in removing liquid from bottles, and the like, without disturbing the sediment in the bottom, and for many other purposes.

Practical Exercises

1. Press a drinking glass or test-tube, mouth down, into a vessel of water. Why does the water not fill it?

2. Why is a so-called empty bottle not really empty?

3. Stop up one end of a glass tube with the finger, fill it with water and invert it, placing the open end in a dish of water. Why does the water not run out?

4. Remove your finger from the end of the tube. Why does the water now run out?

5. Fill a drinking glass with water, cover with a card or piece of stiff paper and, holding the paper with one hand, invert the glass. Why does the water not run out when the hand is removed?

6. If the glass in the above experiment were exactly an inch square in cross-section, how many pounds of water could be supported in this way?

7. Suppose the experiment in exercise 5 had been performed with mercury instead of water. Would the pressure have held up as great a volume of mercury? Why?

8. Examine the nearest barometer and find out how high a column of mercury the air is able to support at the time the observation is made.

9. If it is less than 760 millimeters, account for the difference noted (§104).

10. If the barometer had been made with water instead of mercury, would the column of liquid have been longer or shorter? Why?
11. Would the variations in the height of the column of water be greater or less than in the mercury column? Why?
12. If a bottle is corked at sea level and opened on a mountain top will more air enter or some come out? Why?
13. Fill a bottle with water and cork with a two-hole stopper. Place a finger over one hole in the stopper and invert the bottle. Why does the water not run out?
14. Why does the water run out when the finger is removed?
15. In drinking liquid through a straw, one removes the air from the straw and the liquid rises into the mouth. Explain.
16. In drawing liquids from a barrel or in pouring them from a closed can, the liquid will not run smoothly unless the cap on the can or the bung in the barrel is loosened. Why?
17. Why do liquids run so irregularly from a bottle or jug?
18. Over how high a structure ought one to be able to siphon water at sea level?
19. Could one siphon alcohol or kerosene over a higher structure than he could siphon water? Why?
20. When a break is made in the skin, blood runs out. Does this indicate a pressure within the body greater or less than 15 pounds to the square inch?

21. What effect would moisture in the air be likely to have on the height of the mercury in the barometer?

22. Which do you infer that a falling barometer indicates, fair or stormy weather?

23. Why does smoke fail to rise well from chimneys just before a storm?

24. Why may the stove fail to have a good draft on a rainy day?

25. Spread out one hand, palm downward, and hold a piece of paper about two inches square up against the first and middle fingers where they join the hand. Blow downward between the fingers and the paper will remain in position without being held, as long as one blows. The breath makes a partial vacuum on the upper side of the paper. Explain the pressure that holds the paper in place when it is being blown upon.

26. In the vacuum cleaner, a rapidly revolving fan, consisting of a wheel with curved blades, makes a partial vacuum in the interior of the machine. Explain how this causes the dirt to be swept into the cleaner.

27. The system of pipes that carry away the dust from wood-working machinery, emery wheels, and the like, is essentially part of a huge vacuum cleaner. A similar system of pipes is often used in ventilating mines and large buildings, the impure air being pumped out by this means. Explain how this causes the fresh air to enter.

28. The electric fan works on the principle of the vacuum cleaner, though in this case, it is the outflowing currents of air, instead of those flowing in, that we value. Where is the partial vacuum that is produced by the fan located?

29. Where is the partial vacuum in an atomizer?

30. Why may a wind blowing across a chimney cause a strong upward draft in it?

31. At the mouth of large caves, a current of air flows outward or inward at an approaching change of the weather. In which direction do you infer the current of air will flow just before stormy weather? Why?

32. In correcting barometer readings, it is customary to add certain amounts to the readings of all places above sea level. Why is this necessary in comparing the pressure at different places?

33. Why is it necessary to correct the barometer readings for temperature?

34. What is the total air pressure on the nearest book? Why can you lift the book from the table?

35. How does the varying air pressure ventilate the soil?

CHAPTER XIX

SOLUTIONS

108. **Solutes and Solvents.**—When a quantity of a solid, such as salt, is shaken up in water, it soon disappears in the liquid, or as we say, it *dissolves* or goes into *solution*. If we test the solution thus made, we find that the solid is evenly distributed through it, for all parts are equally salty. Other soluble substances may now be added to this solution and in every instance they act as the salt did and become evenly distributed through it. The substance that disappears in another in this way is called the *solute*, and the substance in which it disappears is the *solvent*. It must not be assumed, however, that because one liquid will dissolve a given solid, that it will dissolve all others. As a matter of fact, there are many exceptions to this rule. Water, for instance, will dissolve salt, but it will not dissolve camphor. Alcohol, on the other hand, will dissolve camphor but not salt. Water is the best solvent known; that is, it will dissolve the greatest number of substances, but alcohol, ether, and some acids are not far behind it in this respect. Water will not dissolve fats, waxes, gums, or resins, though these readily dissolve in some of the other liquids mentioned. Dry-cleaning processes make use of gasoline instead of water as a solvent for the grease and dirt. When alcohol is used as a solvent, the resultant solution is often called a *tincture*. In general, crystalline substances dissolve more readily than those which are amorphous, but there are many exceptions to this rule. A substance that will not dissolve in a given liquid is said to be *insoluble* in it. When in a finely divided state, many insoluble substances will

remain in the liquid for a long time before settling to the bottom. In such cases they are said to be *suspended* in it.

109. Conditions Affecting Solution.—The rapidity with which a substance goes into solution depends somewhat upon its temperature, the size of its particles, and whether the solvent is still or in motion. When dissolving a solid, warming the solvent not only causes the solid to dissolve faster, but increases the capacity of the solvent for it, just as we have seen that heating the air increases its capacity for moisture. At zero Centigrade, 100 grams of water will dissolve 13 grams of saltpeter, but if the water is warmed to 20°C., it will then dissolve 32 grams. Powdering the solid to be dissolved hastens the process since it increases the surface which comes into contact with the liquid. Shaking the solvent also hastens the process since it removes the matter already dissolved from the vicinity of the solute and allows more to be dissolved. Although warming the liquid usually increases its capacity for solids, it has the opposite effect on its capacity for gases. When the temperature of the liquid containing the gas is increased, the gas at once tends to escape. This is seen in a glass of water left standing in a warm room for a time, the bubbles formed on the sides of the glass being the gases driven out as the temperature rose.

110. Strength of Solution.—The strength of a solution depends upon the amount of the solute it contains. If very little is present, it is said to be *weak* or *dilute*; if much is present, it is *strong*. A *concentrated* solution is one that has been made very strong, often by evaporating some of the solvent. A solution that has all of the solid it can hold, is said to be *saturated*. If the temperature of the solution is now increased it can take up more of the solute, but if the temperature is lowered, its capacity is decreased and some of the solute must be dropped, just as cooling the air may cause it to drop some of its moisture as rain. If the liquid containing the solid evaporates,

the solvent alone disappears, and the solute remains behind. A few solutions may be cooled below the saturation point, without causing them to drop any of the solute. Such solutions are said to be *super-saturated*. When a bit of the solute is dropped into such a solution, however, the solution at once throws down the extra solute and returns to the saturated condition again.

111. Crystallization.—When a saturated solution is allowed to cool, or the amount of the solvent is reduced by evaporation or otherwise, particles of the solute begin to appear, usually in definite and characteristic forms known as *crystals*. A crystal, once formed, may go on increasing in size by the addition of more material, but it always maintains its characteristic form. Snowflakes are crystals of water, and sugar and salt are other forms of crystals. In general, the slower the process of crystallization goes on, the larger the crystals are likely to be. When more than one solute is found in a solvent, each tends to crystallize out by itself.

112. Mineral Waters.—Water, as it falls in rain, is nearly pure, but when it sinks into the soil, it begins to take up the soluble materials it encounters so that when it appears again in the form of springs, wells, and the like, it usually holds considerable matter in solution. In many parts of the earth are extensive beds of salt, iron, gypsum and other minerals that have been carried in watery solutions to the places in which they are found, and left as the water evaporated. When water carries enough mineral matter in solution to give it an appreciable flavor, it is called a *mineral water*. The commonest substances in mineral waters are salt, soda, iron, sulphur, and lime. Waters containing considerable potash or soda are called *alkali waters*. In arid regions, the water, after penetrating the soil and dissolving out some of the soluble alkalis, may rise to the surface by capillarity and evaporate, leaving the alkali behind and thus rendering the soil unfit for cultivation.

113. Hard Water.—Hard water is simply water carrying certain mineral compounds in solution. The substances usually found are calcium sulphate, or gypsum (CaSO_4), magnesium sulphate (MgSO_4) and calcium hydrogen carbonate ($\text{Ca}(\text{HCO}_3)_2$), which, instead of producing an agreeable lather with soap, form a scum that fails to cleanse. It is, therefore, customary to add borax, ammonium carbonate, or washing soda which combines with these substances and thus “softens” the water. Water containing calcium hydrogen carbonate is said to be *temporarily hard* because it can be softened by boiling, or by adding slaked lime. This causes the dissolved material to settle to the bottom. In steam boilers when hard waters are used, this accumulation forms a “scale” which causes much trouble by preventing the proper heating of the water. *Permanently hard* water contains calcium sulphate and cannot be softened by boiling.

114. Diffusion.—If a lump of a soluble substance be dropped into a liquid, it will ultimately spread evenly through it, even if the liquid is not stirred. The process by which this is accomplished is known as *diffusion*. A liquid may dissolve in a liquid, or a gas dissolve in a gas, by diffusion, as when illuminating gas escapes from leaking pipes and spreads through a room, or as water vapor disappears in air. In such cases, either gas or liquid may be considered as the solvent, though it is customary to regard the one present in the larger amount as entitled to the name. When a weak and a strong solution of the same kind come into contact, they also mix by diffusion.

115. Other Forms of Solutions.—While the disappearance of a solid in a liquid is the most familiar form of solution, there are various other associations of substances that are fairly included under the title. Gases as well as solids may be dissolved in liquids. The air breathed by fishes and other aquatic animals is thus dissolved in the water. Gases may even be dissolved in solids. Charcoal will take up in this way 40

times its volume of carbon dioxide and 90 times its volume of ammonia. It has such an affinity for bromine gas that if a piece of it is dropped into a jar of this gas, it will absorb it so strongly as to produce a vacuum in the jar. Under proper conditions, charcoal may be made to absorb the air from a vessel, making a more perfect vacuum than can be obtained by the best air pumps. The rare metal palladium will take up 800 times its volume of hydrogen, and spongy platinum absorbs this gas so rapidly that the striking of the molecules against it, soon generates enough heat to raise the gas to the kindling temperature. Self-lighting gas mantles are constructed on this principle. Solids are said to hold gases by *occlusion*. Water may also be dissolved in solids and is then known as *water of crystallization*. When gypsum and certain other minerals are heated, this water is given off, but the crystalline structure is thereby destroyed, and the substance becomes a powder. Plaster of Paris is made by driving the water of crystallization out of gypsum.

116. Alloys.—Homogeneous mixtures of metals are called *alloys*, but in a way these are also solutions. In making alloys, the metals are usually brought to the liquid state, though they may slowly mix even when solid. If gold is placed in close contact with lead and left for a time, particles of it may be found in the lead. Gold readily dissolves in mercury, forming a true solution. When working with mercury, care must be taken not to get it on gold rings and the like. A large number of alloys have important uses. *Brass* is a mixture of copper and zinc. *Bronze* consists mostly of copper, tin and zinc. *German silver* is made of copper, nickel, and zinc and has no silver in it. *Type metal* is composed of lead, tin, and antimony. Alloys very frequently have melting points far below the melting points of the individual metals composing them. Fusible metals used as plugs for automatic fire extinguishers and the like are made of various mixtures of lead, antimony, tin, bis-

muth, and cadmium. Alloys containing mércury are called *amalgams*, and are frequently used by dentists. Our silver and gold coins always contain a certain amount of copper for the purpose of making them harder. Pure gold is said to be 24 carats fine. This is much too soft for use in ornaments and the like. Eighteen-carat or 14-carat gold is commonly used. Zinc, tin, and aluminum are insoluble in most liquids, which explains their use in cooking utensils and other vessels.

117. Solution and Change of State.—Practically all liquids have definite temperature points at which, when pure, they assume gaseous and solid conditions. When a solid is dissolved in a liquid, however, it usually affects both its boiling and freezing points, spreading them apart as it were, by raising the boiling point and lowering the freezing point. Boiling syrup may be made much hotter than boiling water, while brine, made of table salt (sodium chloride) and water, may be cooled to 22° below zero Centigrade before it becomes solid. By the use of another salt, calcium chloride, a brine may be made which does not freeze until the temperature reaches 55° below zero Centigrade. When a liquid is boiling, dissolving a solid in it will reduce its temperature for the reason that, in dissolving, the molecules of the solid are spread much farther apart, and the heat necessary for this is absorbed from the liquid. Salt in contact with ice dissolves in the water from the melting ice and, absorbing heat in the process, forms a brine that does not freeze until a much lower temperature is reached. The heat given out by the brine, as its temperature lowers, goes to melt more ice. This explains the custom of putting salt on icy sidewalks and car tracks in winter. In the ice cream freezer, the cold brine absorbs heat from the cream. In making a freezing mixture of this kind, one part salt and three parts ice is about the right proportion.

118. Emulsions.—Emulsions are not true solutions, but since they consist of substances in close association, they may

be mentioned here. Emulsions may be defined as two substances that will not mix without the addition of a third. One of the substances is usually a fat or an oil. The kerosene emulsion frequently used to kill insects on plants is made of kerosene and water to which is added a quantity of soap. Kerosene and water will not mix, but the soap causes them to form an emulsion. The ingredients in emulsions are likely to separate out if left standing for some time, but readily mix again when well shaken.

Practical Exercises

1. Put a small quantity of clay in one test-tube and a crystal of potassium permanganate in another. Fill each half full of water and shake thoroughly. In which tube is the matter suspended and in which dissolved?
2. Is a solution necessarily colorless?
3. How do you explain the fact that some substances, which will not dissolve in a cold liquid, will dissolve when the liquid is heated?
4. When streams are muddy after a rain, is the material dissolved or suspended in the water?
5. Why is the sea salt, if all the rivers that run into it appear to be fresh?
6. Explain how water may form caves.
7. In caves, stalactites (long points of stone, like icicles) are often formed by water containing mineral matter which seeps through the roof. Explain how the water evaporating may form these objects.
8. Which do you consider the better bluing for laundry purposes, one that is dissolved in the water or one that is suspended in it?

9. Why is the water in shallow wells, especially in cities, usually unfit to drink?

10. Explain how coffee is made by pouring hot water over the coffee in a percolator.

11. Make a saturated solution of nitrate of soda or sal ammoniac and water and put a few drops on a clean sheet of glass, draining off all that does not cling to the glass. What happens to the solute as the solvent evaporates?

12. With a simple lens, examine the material left on the glass. What is the shape of the crystals?

13. Make a dilute solution of table salt and water and place in a broad flat dish to evaporate. How does the shape of the salt crystals compare with those made in the previous experiment?

14. How do you account for the diffusion of gases by the molecular theory of matter?

15. Heat some ammonia water in a florence flask stopped with a one-hole stopper through which is thrust a glass tube. Hold a test-tube over the end of the glass tube and catch some of the ammonia gas driven off. When the tube is full, plunge it, mouth down, into a dish of water. Explain the disappearance of the gas.

16. Could aquatic animals live in water that had first been boiled and then cooled? Why?

17. The "flat" taste of boiled water may be removed by exposing the water to the air for a time, or by shaking it up in a jar with air. Explain.

18. Carbonated water, such as is used at soda fountains, consists of carbon dioxide in solution in the water. Should the water be hot or cold to take up as much carbon dioxide as possible?

19. Account for the lack of pungency or "bite" in a glass of carbonated water that has stood for some time exposed to the air.
20. Household ammonia consists of ammonia gas dissolved in water. When is the cork likelier to pop out of the ammonia bottle, on a cold or on a warm day? Why?
21. How does adding more of a solute affect the density of a solution?
22. Which would freeze earlier in winter, a shallow lake or an equally shallow inlet from the ocean? Why?
23. Why does salting boiling water stop the boiling for a short time?
24. Suppose that on a cool night, ice should form (crystallize) on a quantity of vinegar or sugar and water. Do you infer that the remainder of the solution would be weaker or stronger than before? Why?
25. Water is often said to "purify itself" by freezing. Explain.
26. When the sea in the arctic regions freezes, which do you infer contains the more salt, the water or the ice?
27. What can you say of the seriousness of burns from boiling syrup and the like?
28. Does putting sugar in your coffee, cool or warm it?
29. Why, in fixing the boiling point on the thermometer, must pure water be used?
30. Explain the use of charcoal in deodorizing sick rooms.
31. Milk, butter, and other foods left near strong-smelling substances will take up their odors. Explain how this occurs.

32. In making certain kinds of perfumes, fresh flowers are placed in closed vessels whose walls are covered with a layer of lard or other fat. Later the perfume is found in the fats. How did it get there?

33. Place a crystal of copper sulphate in a test-tube and heat slowly. Explain the source of the substance that forms on the cooler part of the tube.

34. In making alloys, how does melting the metals form an alloy more rapidly than if the two solids were placed together?

35. Milk is a natural emulsion. Can you discover what substance in the milk corresponds to the kerosene in kerosene emulsion?

36. How do soap and water aid in taking grease out of clothing?

37. Cleaning fluid is usually made of several fluids mixed together. Why is this?

CHAPTER XX

PRECIPITATION, FILTRATION, AND DISTILLATION

119. Precipitates.—When two liquids are poured together, one usually dissolves in the other, unless they happen to be liquids that never mix, such as oil and water, but in certain cases, two liquids, instead of forming a solution, make new chemical combinations some of which are not soluble. In such cases, the insoluble matter soon sinks to the bottom. Matter thrown out of a solution in this way is called a *precipitate*. Water and alcohol readily mix, but when alcohol has camphor dissolved in it, the addition of water forces the camphor out of the combination and causes it to appear in the mixture as small white flakes. If the matter *suspended* in a liquid is so finely divided as to settle very slowly, adding other substances to it may cause the particles to come together into larger groups and settle more rapidly. This process is known as *flocculation*. Iron sulphate and alum are substances often used in clearing turbid water by flocculation. Lime added to water in which clay is suspended will also cause flocculation. The particles in clay soils may be flocculated in the same way.

120. Filters and Filtering.—A precipitate may be separated from the liquid containing it by passing it through substances containing many fine pores. Such substances are known as *filters*. In the laboratory, filters are usually made of a special paper, called filter paper, but other filters may be made of charcoal, glass wool, stone, beds of sand, and the like. Only precipitates, or suspended matter, can be separated from

the liquid by filtration, matter in solution passing through unchanged. In many cities, the water for household use is filtered through beds of sand. This gives clear water, but not necessarily pure water, since it does not remove dissolved matter.

121. Distillation.—When it is desired to recover the solid matter in a solution, this is easily accomplished by evaporating the solvent. The solvent may also be obtained in its original

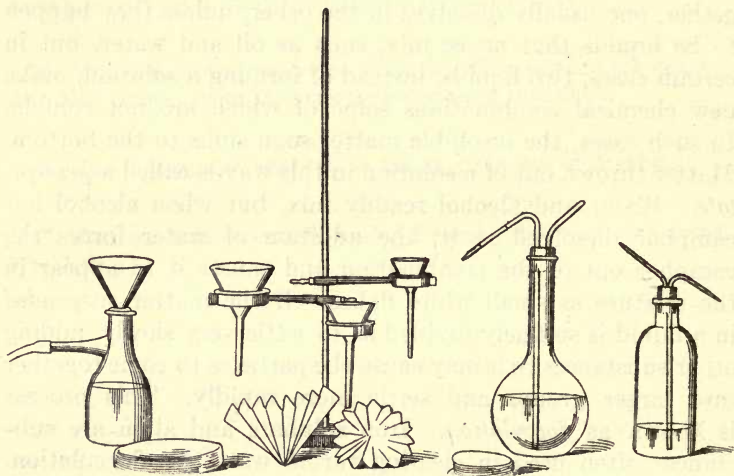


FIG. 46.—Apparatus used in filtering. (Rockwood.)

state by catching the vapor as it rises, and cooling it to the liquid state again. The latter process is called *distillation*. The distilling apparatus consists essentially of a closed vessel in which the matter to be distilled is heated, with a coil of pipe for cooling and condensing the vapor produced. The coil of pipe, often called the “worm,” may be kept cool by being immersed in a tank or stream of running water. The condensed vapor which slowly drops from the coil of pipe,

is called the *distillate*. For purposes of illustration, liquids may be distilled in a florence flask closed by a stopper through which extends a glass tube. The vapor driven off through the

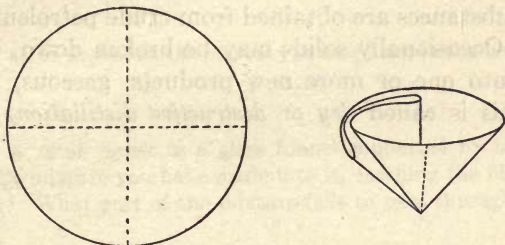


FIG. 47.—How to fold a filter paper.

tube may be condensed by being directed against a bottle of cold water or caught in a test-tube immersed in water. A large number of the fragrant oils used in medicine and the arts

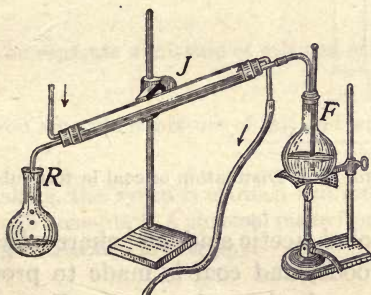


FIG. 48.—Apparatus for distilling in the laboratory. (Tower, Smith and Turton.)

are obtained by distillation. In the same way, alcohol is derived from liquids containing it. When liquids with different boiling points are mixed together, they may be recovered separately by regulating the temperature of the mixture. The

liquid with the lowest boiling point would come off first, followed by others in the order of their boiling points, as the temperature is increased. This is called *fractional distillation*. Naphtha, benzine, gasoline, kerosene, coke, and a large number of other substances are obtained from crude petroleum by this process. Occasionally solids may be broken down, by means of heat, into one or more new products, gaseous, liquid, or solid. This is called *dry* or *destructive distillation*. By this

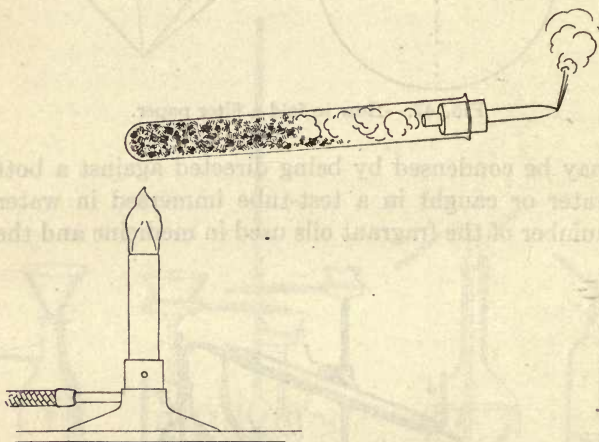


FIG. 49.—Distillation of coal in test-tube.

means wood alcohol, acetic acid, and charcoal are derived from various hard woods, and coal is made to produce coke, tar, illuminating gas, and other substances. From the coal tar are also derived a large number of useful products among which are numerous dyes. The wood alcohol obtained by dry distillation of wood, differs from ordinary alcohol in being very poisonous. Denatured alcohol is ordinary or grain alcohol to which has been added a small quantity of wood alcohol or other substance to render it unfit for internal use.

Practical Exercises

1. Make a solution of about one-half gram of lead nitrate in 10 cubic centimeters of distilled water. To this solution add an equal volume of salt water. What happens when the two solutions are mixed?
2. What term describes the matter you now have in the bottom of the test-tube?
3. Place a filter paper in a glass funnel supported by a ring stand and pour the mixture you have made into it, catching the filtered liquid in a beaker. What part of the mixture fails to pass through the filter?
4. Dissolve some salt in water and filter through a clean filter paper. Taste the liquid that filters through. Does the salt filter out? Why?
5. Shake up a crystal of potassium permanganate in a test-tube and filter. Was this substance dissolved in the water or merely held in suspension?
6. How could you separate a mixture of salt and sand?
7. How could you separate a mixture of salt and water?
8. In sugar making, the syrup is clarified and its color removed by being passed through bone-black, a charcoal made from bones. Explain how the syrup can be clarified in this way.
9. Filters for home use are often made of a layer of charcoal, others have a bottom of fine porous stone through which water filters. What do you infer as to the need for frequently cleaning such filters?
10. Cisterns are often divided by a brick wall, the rain water coming in on one side of the wall and the house supply being pumped away from the other. Of what advantage is this?

11. If alcohol and water were mixed together, which would be driven off first when heat was applied?

12. Sea water is unfit to drink because of various salts dissolved in it. Can you suggest a method of obtaining pure water from sea water?

13. Put about a spoonful of powdered soft coal into a test-tube, cork with a one-hole stopper containing a glass tube. Apply heat from the bunsen burner. What is given off through the glass tube?

14. Will this substance burn?

15. What form of distillation is illustrated by the preceding experiment?

16. Turpentine is obtained from the pitch of various pine trees which is heated with water. The volatile turpentine is driven off and resin or rosin is left. What phase of distillation does this illustrate?

17. In many chemical experiments, it is necessary to use distilled water. Why not use ordinary water?

CHAPTER XXI

ACIDS, BASES AND SALTS

122. Nature of Acids.—The most characteristic thing about acids is their sour taste. In addition, they have the peculiar property of turning certain vegetable juices red or pink. Blue flowers often become pink in the presence of dilute acids, and the change from pink buds to blue flowers is frequently due to the change in the acid contents of the cells. The familiar test for acids is *litmus paper*, made by soaking paper in a solution derived from a kind of plant called a lichen. All acids redden blue litmus paper. Another test for acids is to add them to carbonates, such as limestone or baking soda. With such substances, they produce a bubbling or effervescence, due to the carbon dioxide released. All acids contain hydrogen and all dissolve in water. Acids are very generally distributed throughout the plant and animal kingdom. Among the commonest, are *malic acid* found in apples, *citric acid* in lemons, *acetic acid* in vinegar, *tartaric acid* in grapes, *oxalic acid* in rhubarb, *lactic acid* in sauerkraut and sour milk, *hydrochloric acid* in the stomach of many animals, and *carbonic acid* in the bodies of both animals and plants. Certain other acids are sometimes known as mineral acids. Among these are *nitric*, *sulphuric*, *phosphoric*, and *hydrochloric acids*. The last named is commonly known as *muriatic acid*.

123. Bases.—In many ways, bases are the opposites of acids. This is especially true of their reaction with litmus paper, since they turn red litmus paper blue. Instead of being sour, they usually have a bitter taste, and, when dissolved in

water and rubbed through the fingers, have a slimy feel. Most bases consist of a metal combined with oxygen and hydrogen. Lime-water and ammonia are good examples of bases. When a base is added to a solution of phenolphthalin it is turned a bright scarlet, but the solution becomes colorless again when sufficient acid is added. A strong base is called an *alkali*. Caustic potash (potassium hydroxide) and caustic soda (sodium hydroxide) are two other active bases which are usually known as *lyes*. Both acids and bases attack other substances and corrode them.

124. Formation of Salts.—If an acid be added drop by drop to a base, a mixture may be formed which will not affect either red or blue litmus paper, and which is not corrosive in its action. Such a solution is said to be *neutral*. When a base and an acid neutralize each other in this way, a chemical reaction takes place which results in the formation of a *salt*, in addition to more or less water. Common table salt (sodium chloride) is a familiar example of a salt, and among others with which we are familiar may be mentioned calcium chloride, sodium nitrate, and calcium sulphate. If a mixture is not quite neutral, we may have an *acid salt* or a *basic salt* according to whether the base or acid predominates. Baking soda is a basic salt and therefore affects litmus paper like a base. *Soaps* are really mixtures of salts. When a potash base is used, "soft" or liquid soap is formed. A soda base is used for the hard soap commonly sold. Soft soap may be made hard by the addition of table salt during the process of manufacture. Laundry soaps usually have an excess of alkali which renders them unfit for toilet use.

Practical Exercises

1. Test the substances in the following list with litmus paper and decide which react as acids and which as bases. Those that are not liquid should be dissolved in a little water before testing:

Borax	Molasses
Cream of tartar	Lime-water
Your saliva	Baking soda

2. Place about 10 cubic centimeters of sodium hydroxide (NaOH) in an evaporating dish. Is it an acid or a base?

3. Add hydrochloric acid, drop by drop, to the sodium hydroxide, testing after each addition of acid until the solution is neutral. Be careful not to add too much acid. Evaporate the liquid, taste and name the substance left in the dish.

4. Write the chemical formulas for the acid and base used in the preceding experiment and cross out the chemical elements found in the salt. Can you tell from the remainder, what the liquid was that you evaporated?

5. Baking soda is often added to sour milk to "sweeten" it, that is, to remove the sour taste. Explain how this is accomplished.

6. The pain from insect stings is usually due to formic acid introduced into the wound. Why does the application of ammonia reduce the pain?

7. Strong acids rapidly destroy the skin, clothing, and other substances. If one spilled acid on hands or clothing, what could be used to render the acid harmless?

8. Burns produce an acid condition of the flesh. Why apply lime-water?

9. Soils sometimes become sour through the accumulation in them of acids derived from decaying vegetation. Why will limestone added to such soils "sweeten" them.

10. Soda mints consist largely of baking soda. Why may they be taken to correct sour stomach?

11. In baking, cream of tartar and baking soda are often mixed together and these, in the presence of moisture effervesce and give off much carbon dioxide. It is this gas, increased in volume by the heat of baking, that causes cake, biscuit, and the like to rise. When sour milk is used in baking, cream of tartar may be omitted, but not the soda. Why?

12. When molasses is used in baking, the addition of soda alone will make the cake light. What substance do you infer must be present in the molasses?

13. All baking powders are mixtures of an acid and a carbonate, the latter a salt of carbonic acid and sodium. Usually a small quantity of corn starch is added to keep them apart. Why do they not give off their contained carbon dioxide if the can is kept closed?

14. If baking powder is left exposed to the air, it deteriorates. Why?

15. Why are baking powders always stirred into the flour before moisture is added?

CHAPTER XXII

LIGHT AND VISION

125. Radiation from Luminous Bodies.—When a body is heated very hot, it gives off, in addition to the heat rays, certain other rays which have the power of affecting the retina of the eye, thus producing a sensation which we know as *light*. All bodies which give out light rays are said to be *luminous*. The sun is a luminous body, and so are the stars, but the moon is not because it shines by reflected sunlight. From the fact that light passes easily across space in which there is no matter of any kind, we perceive that the light waves are not waves in air. Scientists regard them as waves in a mysterious substance called *ether*, about which practically nothing is known, but which is supposed to exist between the molecules of matter as well as between the earth and the other heavenly bodies. Though it is almost impossible to study the ether, the waves that occur in it, that is, the heat and light waves, are very well known. The number and direction of their vibrations have been ascertained and their speed has been accurately measured and found to be about 186,000 miles a second. Such a velocity is inconceivable. For all distances on the earth, it is practically instantaneous. In passing from the sun to the earth, however, the distance is so great that about eight minutes are required. We know that light travels in a straight line, because all opaque bodies cast shadows which have the same outlines as the bodies themselves. Moreover, when light enters a dark room through some small opening, we find it always follows a straight path, as is shown by the fact that

the objects it strikes are always in line with the source of light and the opening through which it comes.

126. Reflection of Light.—Though light travels in straight lines, it may be easily diverted or reflected. A sunbeam may be caught on a mirror and turned completely out of its course. By a suitable arrangement of mirrors, its course may be changed again and again. Were it not for the fact that the direction of rays of light can be altered, our eyes would be of little use to us, for most of our seeing is not by direct light, but by light which has first fallen on some object

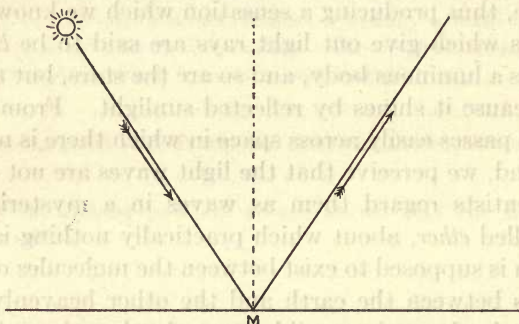


FIG. 50.—Angle of incidence is equal to angle of reflection.

and by it has been reflected to the eye. More than this, unless the object viewed is in direct sunlight, or in the light from some other source of illumination, the light preceding from it has been diverted more than once before it reaches the eye. Rooms into which the sun does not shine during the day are lighted by reflection from the clouds, from dust in the air, from trees, buildings, and similar objects. Smooth surfaces are the best *reflectors* because they turn back the light uniformly. Objects with rough surfaces reflect the light in many directions, each small irregularity acting as a separate mirror, and thus a clear image is impossible. Whenever light

is reflected, it is important to observe that it always leaves the reflecting surface at the same angle as that at which it falls upon it. If we wish to see ourselves in a mirror, we must stand squarely in front of it. If we stand a little to one side, we perceive only objects situated at the same angle to the mirror on the opposite side. The scientific statement of the fact is that "the angle of reflection equals the angle of incidence." The principle is exactly illustrated in bouncing a ball on the ground. If it strikes the earth at an angle, it bounces up and away at the same angle.

127. Refraction.—A ray of light may be turned out of its course in passing through a medium as well as when reflected

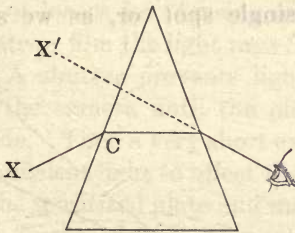


FIG. 51.—A prism changes the direction of a ray of light.

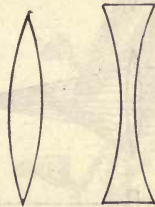


FIG. 52.—Cross-sections of, convex and concave lenses.

from its surface. The turning occurs at the point where the light passes from one medium into another of different density, as from air to water, or from water to glass. If the light strikes the surface of a transparent body at right angles, it goes straight through, but if it strikes at any other angle it is always sent out of its course in the direction of the denser medium. The eye, however, is not cognizant of the changing of the direction of the light rays, and sees the object from which the light is reflected exactly as if the rays were direct. This often results in curious illusions; in fact, the eye is probably more easily deceived than any of our other senses.

128. Lenses.—Circular pieces of glass known as *lenses*, by deflecting the light rays either toward or away from one another, make objects appear to be larger or smaller than they really are. There are several forms of lenses, but the two most frequently used are the *double convex lens*, which is thickest in the middle and curves uniformly to the edge, and the

double concave lens, which is just the reverse of this. When rays of light pass through a double convex lens, owing to the curvature of its surfaces, they are directed toward the thicker part of the lens and made to fall on a single spot, or, as we say, are

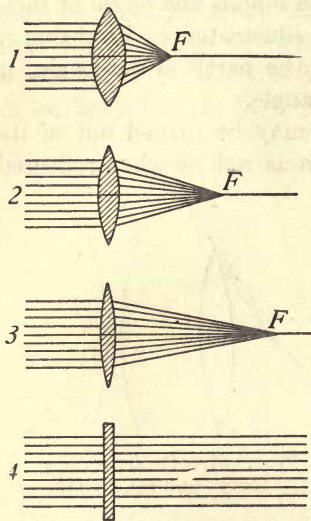


FIG. 53.—How curvature of the lens affects direction of the light rays. (Tower, Smith and Turton.)

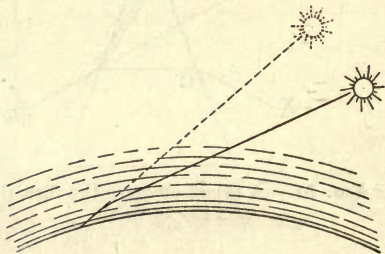


FIG. 54.—Bending of a light ray by atmosphere; sun appears to be higher than it really is.

brought to a *focus*. The very bright spot of light that appears when such a lens is held a short distance above any convenient surface is an illustration of this fact. That heat rays as well as light rays may be focused is well known. The double convex lens is sometimes known as a *burning glass* because the heat rays falling on it may set fire to paper when brought to a focus. When light from an object passes through

such a lens and falls on the eye at the proper focus, the eye estimates the size of the object as if the rays come straight from it, and it therefore appears to be larger, or, as we say, it is *magnified*. The double concave lens is often called a *diminishing glass* because objects viewed through it appear smaller than they really are, due to the spreading of the light rays. The *microscope* and *telescope* consist essentially of two sets of lenses, one at each end of a light-proof tube. The set nearer the object to be viewed produces a magnified image of it within the tube, and this is further magnified by the lenses at the opposite end.

129. The Camera.—The camera is essentially a light-proof box with a suitable set of lenses for focusing on a sensitive plate or film the light rays from an object. A shutter prevents light from entering the camera until the picture is to be made. Then a very short exposure admits sufficient light to affect the emulsion on the sensitized plate and make the picture. In this picture, or *negative*, the light and shade of nature are exactly reversed, since light objects reflect the most light into the camera and produce the greatest change in, or darkening of, the sensitized surface. When prints are made from negatives, however, the darker parts hold back the light more than others and thus the finished photograph reproduces the original scene in its proper lights and shades. The *projection lantern* or *stereopticon* is like a camera reversed. The light is sent through a semi-transparent slide and enlarged by a suitable set of lenses as it is projected on the screen. The eye is also much like the camera. The cornea and crystalline lens focus the rays of light on the retina or sensitive part at the back of the

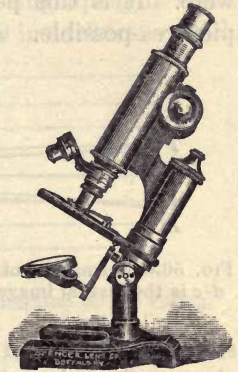


FIG. 55.—Microscope.

eye, and the iris, like the opening in the shutter, can be enlarged or diminished to admit the proper amount of light. In our eyes, a continuous picture is produced as long as the eyes are open, and no shutter to keep out the light is necessary, though the eyelids may function like shutters on occasion.

130. Persistence of Images.—When an image is formed on the retina, it does not vanish instantly, but persists for about $\frac{1}{10}$ second. A glowing stick whirled about on a dark night, therefore, appears like a fiery circle since it is seen in several positions in a short space of time and the images overlap as it were. It is this peculiarity of the eye that makes moving pictures possible. A series of pictures, each differing slightly

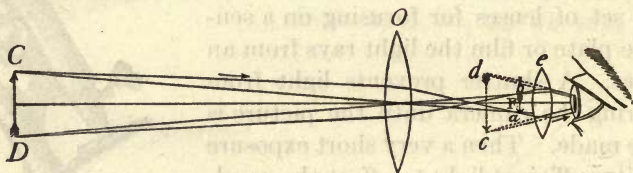


FIG. 56.—Formation of an image by a telescope. *b-a* is the real image; *d-c* is the virtual image seen by the observer. (Tower, Smith and Turton.)

from the one which precedes it, are thrown on the screen and these, reflected to the retina, blend into a picture in which the figures seem to move. The eye may be easily deceived in other ways. For instance, a square ruled with perpendicular lines appears to be shorter than one ruled with horizontal lines.

131. Various Effects of Light.—Since light is a form of energy, it is not surprising to note that it causes numerous changes in matter. Most of these effects are probably chemical in nature, as the fading of colors, the tanning of the skin, and the killing of germs. Hydrogen and chlorine mixed in the dark are inert and do not change, but if a ray of sunlight strike them, they combine with explosive violence. Another famil-

iar instance of chemical change caused by light is the decomposition of matter on the photographic plate when the picture is made. The most important use of light to the world is in supplying the energy needed by all plant life, and (since animals are entirely dependent on plants) of all animal life as well. The green cells of plants turn the light energy into electric energy and by its aid combine the materials absorbed from the soil and air into food. Plants are the only living things that can thus form food from chemical elements.

132. Phosphorescence.—A large number of substances are now known which have the power of storing up light when exposed to the sun's rays, and of giving it off in darkness. Such

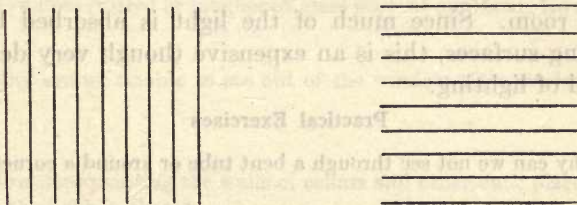


FIG. 57.—Apparent size of square affected by direction of the ruling.

substances are said to be *phosphorescent*. In all cases the wave lengths of the light given out are longer than those taken in. Some substances may be made phosphorescent by friction, hammering, or splitting, and others are affected by electricity, heating, etc. Various plants give out rays of light in the dark, and a large number of the lower animals also have this power. The fireflies and glowworms are good illustrations. The phosphorescence which often crests the waves in the warmer parts of the globe is caused by minute one-celled animals. Luminous paint is now made from substances which are strongly phosphorescent. This paint absorbs light during the day and emits it at night, and is therefore of value for covering matchboxes and other objects which need to be located in the dark.

133. Artificial Lighting.—The light from artificial sources of illumination is of varying intensity, which is usually expressed in candlepower, the candlepower being defined as the amount of light given by a sperm candle burning about 8 grams of wax an hour. In lighting our dwellings and shops, the most satisfactory light is that which comes from above in much the same way that the light from the sun does. Diffused light is also better than direct light. One should avoid too much light on book or work and should never sit facing the light. In our dwellings, lights are commonly surrounded by shades designed to reflect the light in many directions and so diffuse it. Another method of securing diffused light is by the so-called *indirect lighting*, in which the light is reflected from the ceilings of the room. Since much of the light is absorbed by the reflecting surfaces, this is an expensive though very desirable method of lighting.

Practical Exercises

1. Why can we not see through a bent tube or around a corner?
2. Can you think of a way of making objects around a corner visible?
3. Why can a carpenter tell if a board is straight, by sighting along it?
4. Trace the rays of light which enable you to see yourself in a mirror.
5. Why can we not see in absolute darkness?
6. What makes a beam of light visible when it is thrown across a dark room?
7. Explain the appearance of "the sun drawing water."
8. Why does it not become dark as soon as the sun sets?

9. In the tropics, twilight is much shorter than in temperate regions, and near the poles, it is much longer. Why? (What part of the earth turns away from the sun most rapidly?)

10. How does seeing the candle flame differ from seeing the candle?

11. Why is a snowflake or ground glass white, when water and glass are transparent?

12. Why does a piece of white cloth or a light soil turn darker when wet?

13. How does frosted or roughened glass prevent our seeing through it?

14. Why are we unable to see out of the window after the lamps are lighted?

15. How does painting the walls of cellars and other dark places white increase the light in them?

16. Put a coin in a moderately deep basin and stand so that the coin is just hidden from view by the edge of the vessel. Let a classmate slowly pour water into the basin without disturbing the coin. How does this affect your seeing it?

17. Explain how this effect was produced.

18. Why does a pole projecting from the water appear to be bent at the surface of the water?

19. Put a spoon in a glass of water and, looking down on it, place your finger on the outside of the glass at the point where the spoon seems to touch it. How does this compare with the real position of the spoon?

20. Would you say that ponds are deeper or shallower than they appear to be?

21. In spearing a fish, ought one to aim a little above or a little below it, as it appears in the water?

22. Recalling the different densities of the air at sea level and at high altitudes, tell whether the sun's rays are bent toward or away from the earth at sunrise and sunset?

23. Explain how we can see the sun after it has really set, or before it has risen?

24. In the short-sighted or near-sighted eye, the rays of light come to a focus before reaching the retina. Do such eyes need concave or convex glasses? Why?

25. What kind of glasses should the far-sighted eye be fitted with if in such eyes the light does not come to a focus when it reaches the retina?

26. Could a burning lens be made of ice?

27. When an object is viewed through a double convex lens, why is the image blurred except when the glass is held at a definite distance from the object?

28. By means of a mirror, examine the pupil of your eye after looking at an object in bright light, and again after being in a dim light. What effect on the size of the pupil has an increase or decrease in the amount of light?

29. Would you expect the pupil of the eye to be expanded or contracted when one is walking at dusk?

30. Why do owls have such large openings in the iris?

31. Why is one dazzled when brought suddenly from darkness into a brightly lighted room?

32. Why is it difficult to see when we first go into the dark from a lighted room.

33. On a dark night, one is able to see fairly well after he has been in the dark for some time. Why?

34. Why are cameras always painted black inside?

35. The interior of the ordinary human eye is black but albinos lack this pigment. Albinos cannot see well in bright light. Why?

36. Hold a pencil a few inches from the eye and look at some point beyond it, first with one eye and then with the other. What advantage is there in judging distances, size, and shape in having two eyes?

37. Punch a hole in each end of a small card, such as a visiting card, and in each hole tie a piece of twine. Draw a cage on one side of the card and an animal exactly opposite on the other. Revolve the card by means of the twine and explain the effect produced.

38. How many distinct and consecutive objects can one see in a second?

CHAPTER XXIII

COLOR

134. Composition of Light.—Light, as it ordinarily comes to us from the sun, is called *white light*, but if a beam of this light be directed through a glass prism, we discover that, instead of white light, we have a band of several different colors called the *primary* or *prismatic colors*, with red at one end, violet at the other, and orange, yellow, green, blue, and indigo between.

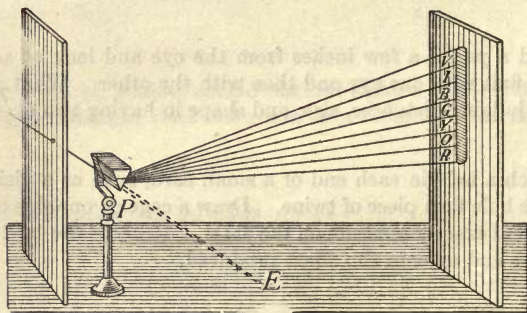


FIG. 58.—Formation of the spectrum by a prism. (Tower, Smith and Turton.)

The colors are due to differences in the speed with which the rays of light vibrate and the resultant effects of these rays on the eye. Those which give us the sensation of red, vibrate 392,000,000,000,000 times a second, while the violet rays vibrate more than twice as fast. Passing light through a prism merely serves to sort out the different rays. If these are brought to a focus by a lens, or are mixed in any other way,

we get white light again. The *rainbow* is a natural spectrum into which light is broken up by falling raindrops. Small rainbows may often be seen in the spray from waterfalls, lawn sprinklers, and the like. The misty halos sometimes noticed encircling the moon and regarded as the forerunners of stormy weather are due to similar causes. Other examples of refracted sunlight are the brilliant colors of the sky at sunrise and sunset. The composition of light may be studied by means of the *spectroscope*. This consists essentially of a

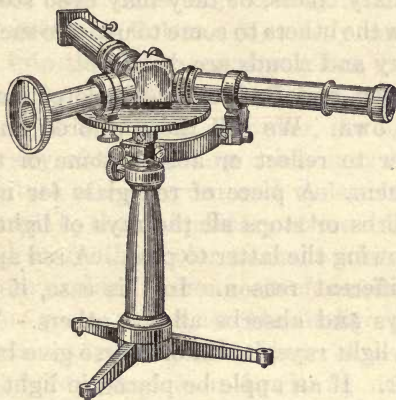


FIG. 59.—The spectroscope. (Tower, Smith and Turton.)

prism with means for magnifying and measuring the rays of light passing through it. All luminous bodies give out characteristic rays. When a gas is heated enough to glow, it produces a set of colored lines in the spectroscope, which are known as its *spectrum*. By means of the spectroscope, the light from distant stars has been examined and the elements composing them identified. Only a few of the vibrations coming to us in sunlight are perceptible to the eye. Beyond the red end of the *solar spectrum*, as it is called, are still slower

infra-red rays which the eye fails utterly to note, but which when properly handled, will affect the photographic plate. In this region of the spectrum the majority of the heat rays also occur. Beyond the violet end of the spectrum are the *ultra-violet* rays. Some of these vibrate 1,500,000,000,000,000 times a second. These rays kill germs, cause skin to tan and freckle, and may even be used for making photographs, though most of the rays which make ordinary photographs are found in the violet end of the spectrum. Fine particles of dust, water, or ice may act like a prism in breaking up light into these primary colors, or they may even stop some of the colors and allow the others to come to us. To such causes many colors of the sky and clouds are due.

135. Absorption and Reflection.—Colored bodies have no colors of their own. We call them colored only when they have the power to reflect or absorb some of the light rays falling upon them. A piece of red glass for instance is red because it absorbs or stops all the rays of light except those we call red, allowing the latter to pass. A red apple, however, is red for a different reason. In this case, it sorts out and reflects red rays and absorbs all the others. When a body absorbs all the light rays, it will of course give back none, and we call it black. If an apple be placed in light which has no red rays in it, there will be none to reflect, and it will consequently appear black. Placing a green object in red light would have the same effect. The energy of the colors absorbed is changed to heat which gives reason for the statement that black clothing is warmer than white. Red, being nearer the warm end of the spectrum, is properly called a warm color, while blue and violet are known as cold colors. White, as we have seen, is a mixture of all the colors.

136. Fluorescence.—Some bodies have the power to change the color of the light falling upon them and are said to be *fluorescent*. In fluorescence, as in phosphorescence, the rays

given out are always slower than those taken in. A solution of chlorophyll, the green coloring matter of plants, is green by transmitted light, but the light reflected from it has a reddish hue. Kerosene is also strongly fluorescent. The greenish color often reflected from the eyes of animals at night is probably also due to fluorescence. The X-rays, or Roentgen rays, used for locating broken bones, bullets, and the like in the human body, are not visible to the eye, but owing to the fact that they excite fluorescence in various substances, we are able to construct a *fluoroscope* by means of which the shadows of the bones and other dense objects may be studied.

137. Complementary Colors.—Not only may white light be broken up into the seven primary colors, but we can produce white light by a proper mixture of these colors. If any of the seven colors be missing, however, the light will not be white. Since any of the primary colors may be produced by the proper mixture of red, green and violet-blue, these latter are often regarded as the real primary colors. The color which must be added to another color to make white light is called its complementary color. Among sets of complementary colors are red and blue-green, yellow and blue-indigo, greenish-yellow and violet, and orange and light blue. A colored object is always made more conspicuous by being near its complementary color. It is to be noted that when pigments are mixed, they do not always give results in accordance with the statement just made, for the reason that pigments are not colors but substances which reflect colors. Yellow and blue rays give *white light*, but yellow and blue pigments give *green color*. Colors differ considerably in their carrying power, and this does not depend entirely upon their wave length. Yellow is visible from the greatest distance. As the twilight deepens, blue flowers are the first to become indistinguishable, then follow the red and pink, but the yellow are usually visible except on the darkest nights.

138. The Eye and Color.—Color, as we have seen, is really a sensation set up in the retina by light of a certain wave length and from the retina transmitted to the brain. There seem to be three sets of these nerve endings sensitive to red, green and blue respectively. When any of these are defective or refuse to carry their proper sensations, the eye will be color-blind. A person color-blind for red will have difficulty in distinguishing a red apple from the green leaves by color alone. Yellow and blue are the colors most easily distinguished by the color-blind. The nerves which carry color sensations are easily tired and, if overtaxed, may fail to report accurately for a time. When one looks intently at a red object for a few seconds and then at a white wall or curtain, he will see the image of the object in green, since the tired nerves do not now respond to that color in ordinary light and only the complementary colors are reported to the brain.

Practical Exercises

1. How many times is a beam of light turned in passing through a prism?
2. Why do openings into dark places such as cellars, always appear black?
3. Why does the pupil of the eye appear black?
4. Why is the interior of a camera always painted black?
5. Put a strong solution of soap and water in a flask and look through it toward the light. What is its general color?
6. Look at the flask by reflected light. What is the general color?
7. How did the particles of soap in the water produce the effects noted in the foregoing experiments?

8. Look at the sun through a piece of smoked glass, and explain the change in color noted.

9. What causes the sun to have a red hue at sunset?

10. Why does the sky appear blue?

11. What color would the sky be if there were no dust in the air?

12. Why do distant hills always look blue?

13. What effect does the absence of dust have on twilight?

14. When are the colors of sunset brightest, on a clear or on a partly cloudy day? Why?

15. What rays of light do plants absorb?

16. Look at a blue object through a red glass. Explain the change in color.

17. What color would a red object appear in blue light? Why?

18. Look at a white object through three combined sheets of glass, red, green, and blue respectively. Explain the result.

19. The mercury-vapor lamp, much used in factories, photograph studios, and the like, give a bluish-green light with few or no red rays. What would be the effect of putting a red glass chimney over the light?

20. Why do people look pale in blue light?

21. Why is it difficult to match colors by artificial light?

22. Why is bluing added to water in which clothes are rinsed in laundering?

23. What color of paper is best for wrapping up white goods to give them a white appearance?

24. Should a girl with red hair wear blue? Why?

25. Hold a piece of green glass before one eye, and a piece of red glass before the other, and look at some white object for a few minutes. Then look through one of the glasses, first with one eye and then the other. Explain the difference in the brightness of the color noted.

26. Cut various shapes out of black paper. Lay them on a green or red surface, such as a book cover, and cover them with a thin sheet of white tissue paper. Hold in the light and explain the apparent color of the objects.

27. Why does the photographer find it necessary to use a red or orange light in his dark room?

28. Examine plants grown in the dark, or the grass over which a board has lain for a few days. What effect has light on the color of plants?

29. Why does a blue dress look black in red light?

30. In photographing colored objects, a color-screen of light yellow glass is often used. How does this assist the reds and yellows to register properly?

CHAPTER XXIV

SOUND

139. Vibrations in Air.—Sound, like light, consists of vibrations which excite certain of our nerve endings and cause characteristic sensations to be transmitted to the brain. In one case, the vibrations fall on the retina producing light, vision, and color; in the other, they fall on the ear and cause sensations of hearing. Sound differs from light in consisting of waves in ordinary matter instead of in the ether, and in consequence they move much more slowly and cannot cross a

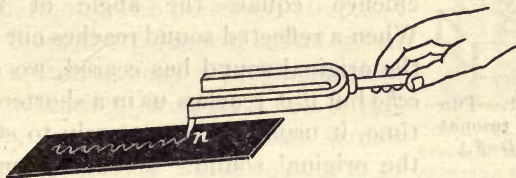


FIG. 60.—Recording the vibrations of a tuning fork.

vacuum. The speed of sound is also affected by the medium in which it travels. In ordinary air, it moves about 1100 feet a second, in water nearly five times as fast, and in iron or steel fifteen times as fast. Even this latter speed is in marked contrast to the speed of light, which is nearly 186,000 miles a second under all circumstances. In general, the denser the substance, the more rapidly sound travels in it, though this statement is subject to some modifications since the elasticity of the substance in which it moves must also be taken into

account. Sound moves most rapidly in elastic bodies. Since adding moisture to the air increases its elasticity, we commonly hear distant sounds more distinctly just before a storm. Sound waves may be thought of as a series of alternating compressions and rarifications in the mediums through which they pass. They tend to spread out in all directions from their source and thus, coming constantly into contact with a greater number of molecules which must be caused to vibrate, they gradually lose their energy and diminish in intensity. When sound waves are kept from spreading, as in the speaking-tube or *megaphone*, they carry much farther. The reason one can usually hear sounds so distinctly across the water is because the layers of denser air above the water prevent the sound from rising.

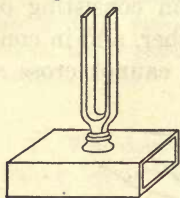


FIG. 61.—Tuning-fork on resonating box. (Duff.)

140. Echoes.—Sound, like light, may be turned or reflected, and can also be brought to a focus. When reflected, the angle of incidence equals the angle of reflection. When a reflected sound reaches our ears after the original sound has ceased, we call it an *echo* but if it reaches us in a shorter period of time, it usually serves merely to strengthen the original sound. Since the sensation of

sound persists about $\frac{1}{10}$ second, the reflecting surface must be at least 56 feet away to cause an echo. If nearer, the sound waves would have time to go and return before the original sound ceased. Echoes, however, may be produced from surfaces much nearer the observer, but, in such cases, the waves are reflected from one surface to another just as light may be reflected from one mirror to another. The usual reflecting surface is a wall, wood, or cliff, but, on occasion, clouds or layers of air of different density may serve as reflecting surfaces also. A *sounding-board* is often placed back of the speaker's platform in large rooms to reinforce the tones of the speaker. When

no reflecting surfaces are near, it is much more difficult to hear the speaker. This explains the difficulty one has in understanding a speaker in the open air. When sound is reflected from several surfaces at different distances, a succession of echoes following close upon one another may be produced. These we call *reverberations*. The roll of thunder is thus produced by the reflection of the original sound from different clouds.

141. Sympathetic Vibrations.—The time required for one vibration of a body is called its *period*. If a vibrating body be brought near another with the same period, the latter will soon begin to vibrate in harmony with it. Vibrations of this kind are called *sympathetic vibrations*. Other bodies may be forced to vibrate out of their natural period when brought into contact with a vibrating body. Thus the body of a violin vibrates in harmony with the strings stretched across it. Since the volume of sound given out by the vibrating body is proportional to the surface vibrating, *forced vibrations* of this kind largely increase the original sound. The property of a body which enables it to vibrate in harmony with another is called *resonance*.

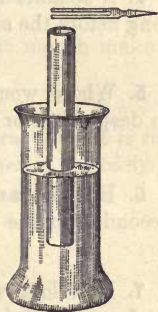


FIG. 61.—A convenient method of changing the length of a vibrating air column.

142. Distinguishing Sounds.—When a musical note is sounded, there is produced, in addition to the fundamental tone, a variety of others, known as overtones, that give character to the different musical sounds and enable us to distinguish the notes of different instruments in an orchestra, to recognize the voices of our friends over the telephone, and the like. Should these overtones be suppressed, the ear would be unable to distinguish the notes produced by the piano or flute from those of the human voice.

Practical Exercises

1. How does clapping the hands or firing a cannon produce sound?
2. Recall the playing of a band at a distance. Do different sounds have different rates of speed, or do they travel with the same speed in the same medium?
3. How far away is the lightning if the thunder is heard three seconds after the flash is seen?
4. A steamer five miles from shore is seen to blow her whistle. How long before the sound would be heard by a person on shore?
5. Where would you expect conversation to be more easily heard, in deep mines or on mountain tops? Why?
6. How far away is the reflecting surface if an echo is heard half a second after the original sound?
7. How long will it take for an echo to reach you if the reflecting surface is 1100 feet away?
8. Could one hear better by placing the small end of a megaphone to the ear? Why?
9. Why are echoes more likely to occur in a large than in a small room?
10. Why do empty rooms often produce echoes when the same rooms furnished do not?
11. When a sea-shell is held to the ear, a roaring sound, which some people believe to be the roaring of the sea, can be heard. What causes the sound?

12. When a comb is drawn rapidly across the edge of a card, would you consider the sound produced a musical sound or only noise?

13. Suppose the card held on the rim of a rapidly revolving and regularly notched wheel. Would you call the sound music or noise?

14. Why do the wings of a bee make a musical note when the wings of a bird in flight do not?

15. Of what use is the reed or thin flap of metal in a harmonica or mouth organ?

16. How does placing the Jew's-harp in front of the mouth make it sound louder?

17. Stretch a string across two supports in such a way that it is free to vibrate. When does it give out the higher note, when it is loosely or tightly stretched?

18. When does it vibrate most rapidly?

19. Using the finger for a support, cause different lengths of the string to vibrate. Which gives off the higher note, a short or a long string?

20. Is the foregoing true of pianos, harps, and violins?

21. Explain the humming of telegraph and telephone wires.

22. What produces the sounds in an æolian harp?

23. Which would you expect to give the higher note, a large or a small tuning fork?

24. Suppose the wheel mentioned in question 13 to have its speed suddenly increased. What effect would this have on the tone produced?

25. Strike a tuning fork and immediately hold the base of the fork on the top of a wooden table or a wooden box. Explain the sound produced.

26. Strike the fork again and hold it over the mouth of a tall cylinder. Pour water into the cylinder, a little at a time, until you get a clear note from the cylinder. How does the column of air in the cylinder, vibrating in sympathy with the fork, affect the original sound?

27. Try a tuning fork of a different size. Does the air column vibrate with any sound or only those with which it is in sympathy?

28. Using the loud pedal of the piano, sound a full note with the voice and account for the response from the piano.

29. Why do the windows of a church sometimes rattle when a particularly deep note is played on the organ?

30. Draw a small glass tube out to a slender point, attach it to a gas jet by a rubber tube, fix in an upright position, and light the gas. Now slowly pass a longer and larger tube over the flame. Account for the sound produced.

31. What gives resonance to the flute or fife?

32. What gives resonance to the drum?

33. What part of the respiratory tract gives resonance to the human voice?

34. How many notes in the musical scale?

35. Is there a single scale or will any other series of tones with the same difference in vibration produce a scale?

36. In the xylophone, a scale is produced by pieces of wood of different lengths. Explain.

CHAPTER XXV

FORCE AND MOVING BODIES

143. Momentum and Inertia.—When a body is at rest, it cannot be moved without applying some external force to it; that is, energy must act upon it in order to move it. When it is once set in motion, however, it offers a similar resistance to any effort to stop it. The resistance which a body thus offers to any attempt to change its condition is called its *inertia*. If a moving body meets with no opposition, it will go on in a straight line forever. On the earth, however, bodies ultimately meet with enough resistance in rubbing against the air or other forms of matter to bring their motion to an end. When a body is in motion, the resistance which it offers to being stopped is spoken of as its *momentum*. Momentum is not the same as speed, however, for a heavy body, such as a cannon-ball, moving slowly may offer more resistance to being stopped than a lighter body moving with a much higher speed. If a second force be applied to a moving body, its effects depend upon the direction from which it is applied. If applied in the direction in which the body is moving, it increases its speed; if applied in the opposite direction, it reduces the speed, or, if large enough, may either stop it entirely or cause it to move in the opposite direction. If applied in any other direction, the body will take a new course which is the exact average of the two courses which it would have followed had each force acted separately upon it. We have an illustration of this when any heavy object is tied to a string and swung around in a circle. The moving body tends to fly away in a straight line, but being constantly pulled out of its

course by the string, it takes a circular path. When a wheel or other object is rotating, there is always present this tendency for each particle to fly off into space. The particular force which causes this is called the *centrifugal force*. Any force which tends to pull the particles of a moving body toward the center of a circle is called the *centripetal force*. In all cases where a force acts, there is a reaction equal to the action. A moving body may be stopped only when the resistance to its progress is equal to its momentum. If the resistance is greater than the momentum, as when we strike a moving ball with a bat moving in the opposite direction, a new motion may be set up which is due to the excess momentum from the bat which is now imparted to the ball.

144. Friction.—The resistance which moving bodies meet in rubbing past other bodies is called *friction*. This resistance is due to the fact that surfaces which appear smooth are never entirely so. Even polished surfaces, such as glass and metal, appear minutely roughened when viewed with a microscope. When two surfaces are in contact, their irregularities fit into one another and thus develop resistance to the passage of the one over the other. In practice, it has been found that a given body will often move over a body of an entirely different substance more readily than over another body like itself. This is because different substances may have different irregularities in them and therefore fail to completely interlock. For this reason, the journals in which steel shafts turn are often made of brass or babbitt metal. Owing to the nature of the motion, *rolling friction*, as when a ball or wheel rolls on a surface, develops less resistance than *sliding friction* in which one surface simply slides over another. The effort needed to overcome friction at starting is much greater than is required to keep the body moving after once started. In either case, however, the friction is proportional to the pressure; the heavier the body to be moved, the greater the effort

needed to move it. Oil, grease, and graphite fill up the irregularities of surfaces in contact and thus reduce friction. The area of the surfaces in contact does not usually affect friction, nor does an increase in speed when a solid is moving over another solid, but when the solid is moving in water or air, friction increases with speed. It requires proportionately more energy to drive a train or steamship at high speed than it does to run them at a more moderate velocity.

145. Advantages of Friction.—Friction has its advantages as well as its disadvantages. Were it not for friction, nails would not hold, belts would slip over pulleys without turning them, and walking would be impossible. We realize the truth of the latter statement when we attempt to walk on smooth ice or a highly polished floor. Sawing, filing, polishing, and similar operations could not proceed without friction. The sand-blast for cutting designs on glass and the like, also owes its efficiency to friction.

146. Gravity.—An important force tending to move all bodies is called *gravity*. This is a mysterious attraction existing throughout the universe which tends to draw all bodies toward one another. The pull of gravity is exactly proportional to the mass of the body. A heavy body therefore exerts a stronger pull than a lighter one, but it exerts no more pull in proportion to its mass. Gravity also acts as if the entire mass of the body were at the center of its mass. It decreases rapidly as the distance between these centers increases, but notwithstanding this, it is gravity that keeps the stars, suns, and planets in their proper paths. The same force acting between the sun, moon, and earth, is the cause of the *tides*. It is also the attraction of the earth for all bodies upon it that gives them weight. When we lift anything, we exert sufficient force to overcome the pull of the earth upon it. When gravity is the only force acting on a falling body, its path is a straight line toward the center of the earth. Masons,

carpenters, and other artisans make use of this force by means of the plumb-bob, a top-shaped piece of metal suspended by a string. The string always takes a position perpendicular to the earth's surface, and a line at right angles to this is horizontal.

147. Equilibrium.—Since the attraction of gravity always acts toward the center of its mass, the center of gravity in a body is that point upon which it will exactly balance itself. When this center is near the base of the body, as in a book lying on its side, it resists any attempt to change its position or upset it. It is therefore said to be in *stable equilibrium*. If, however, the center of gravity is so located that moving the body will lower the center of gravity, the body is in an *unstable equilibrium* and easily upset. A meter stick standing on end is in unstable equilibrium. In a few bodies, a ball for instance, the center of gravity is so placed that moving them neither raises nor lowers it. Such bodies are said to be in *neutral equilibrium*.

Practical Exercises

1. Why cannot one fire a rifle around a tree?
2. Why can one jump farther with a running start than he can without?
3. Why does a heavy flywheel cause machines to run more smoothly?
4. Why may one escape a close pursuer by dodging?
5. How does beating a carpet get the dust out of it?
6. When a car suddenly goes around a curve in which direction are the passengers thrown, toward or away from the center of the curve? Why?

7. When a car in which we are riding stops suddenly, we are thrown forward. Why?

8. In what direction are we thrown when a car starts suddenly? Why?

9. In carrying a glass full of water, why is it likely to spill if we stop suddenly?

10. Lay a small card over the mouth of a drinking glass and put a coin on the card. Drive the card away horizontally by a smart snap of the finger and explain the action of the coin.

11. Place a penny on a cloth-covered table and invert over it a drinking glass propped up by three larger coins. By scratching on the cloth near the penny, it may be made to creep out from under the glass. Explain.

12. Why is one likely to be thrown down when jumping from a rapidly moving vehicle?

13. Why, in jumping from a small boat, does the boat move away as we jump?

14. How is it possible to drive a nail by striking it with a hammer?

15. When one cracks an egg by striking it against a hard object, is it action or reaction that breaks the shell?

16. Mud which will stick to a slowly revolving wheel will be thrown off when the wheel moves faster. Why?

17. Grindstones, emery wheels, and the like are sometimes turned so fast that they break. Why?

18. Why can one whirl a bucket of water in a perpendicular circle without spilling it?

19. In large laundries, the clothes are often dried by being placed in a cylinder having many openings and revolved rapidly. How does this dry the clothes?

20. The cream separator used in dairies is essentially a rapidly revolving bowl into which the milk is run. Do you infer that the cream goes to the center or to the outer part of the bowl. Why?

21. Where does a stream run faster, near the banks or in midstream? Why?

22. Would an increase in the friction between the wheels of a locomotive and the rails be advantageous or not? Why?

23. Explain the use of sand on the rails when the track is slippery.

24. A sheet of paper flutters to the ground but the same paper made into a ball falls more rapidly. Why?

25. Why will a coin fall to the ground more quickly than a feather?

26. Why do ball bearings make machines run more easily?

27. Why are the shafts of fine watches set in bearings made of precious stones?

28. On which would a marble roll farther, a bare floor or one covered with carpet? Why?

29. Why is it more difficult to walk against a stiff breeze than against a light one?

30. How does applying brakes to the wheels of a train reduce its speed?

31. What force do we overcome when we drive a nail?

32. The earth travels around the sun in a nearly circular path. Can you explain why the attraction of gravity does not cause it to fall into the sun?

33. Recalling the shape of the earth, decide whether a piece of gold weighing exactly an ounce at the north pole would weigh more or less if carried to the equator?

34. Where would a body weigh more, at sea-level or on a mountain top? Why?

35. The planet Jupiter is much larger than the earth. If it has the same density as the earth, would a man weigh more or less if transported to Jupiter? Why?

36. Suppose the earth to rotate twice as fast as it does at present. What effect would this have on the weight of objects? Why?

37. Name the kinds of equilibrium represented by the following: a ball on a sloping surface, a moving pendulum, a cone resting on its side, a cone resting on its base, a spinning top, a cube of wood, an egg, walking a rope, a man standing.

38. When one stands erect, is the center of gravity above or below the point of support?

39. Why is it so difficult to stand up in a small boat?

40. Why do we lean forward when getting up from a chair?

41. When one is carrying a bucket of water or other heavy object in one hand, why is the other held away from the body?

42. Why do we lean forward when walking up hill?

43. Why do we swing our arms when we walk?

44. Stand with your back to the wall and without moving the feet, try to pick up an object placed at the toe of your shoe. Explain your failure.

45. Explain how "walking is a perpetual falling."

46. What causes the great pressure at the bottom of the ocean?

CHAPTER XXVI

LONGITUDE AND TIME

148. Locating Points on a Globe.—It would be very difficult to indicate a point upon a stationary ball or globe, for it has neither up nor down, sides nor ends, nor points of the compass. When such a body is rotating, however, the task becomes very easy. We have only to call the imaginary line about which it spins its *axis*, and the two points where this line comes to the surface, its *poles*, to get two locations upon it that do not change. If a set of lines are now imagined passing around the globe through these poles, and another set extending around it at right angles to them, any place may readily be located by noting its distance from the nearest line of each set. The earth is such a globe, and the location of points upon it is determined in this manner. If one turns his back to the sun at noon in our part of the world, he will be facing that pole called the *north pole*. The direction on his right will be *east* and on his left *west*. *South* will be behind him. The circles passing through the poles are known as *meridians*, and those running at right angles to these are *parallels*. The distance of a place from a given meridian, expressed in degrees, is called its *longitude*, and the distance north or south of the great circle, called the *equator*, that passes around the earth midway between the poles is its *latitude*.

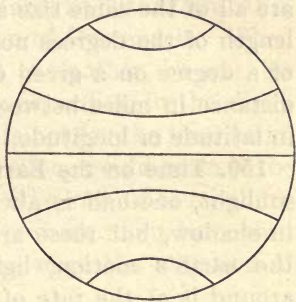


FIG. 63.—Important circles on the earth.

149. Distances on the Earth.—Since the earth makes one rotation on its axis every 24 hours, we can express distances east and west around the earth in terms of either time, length, or longitude. In north and south directions we can express distance only in terms of length or latitude, because it is the turning of the earth on its axis that gives us the measure of time. The distance around the earth at the equator is about 25,000 miles, and since every circle has 360 degrees in it, the length of one degree on the equator would be nearly 72 miles. North and south of the equator, however, the circles grow successively smaller and the length of a degree is necessarily shorter also, but the same number of degrees pass beneath the sun every hour, no matter where located. The great circles, or meridians, which pass north and south through the poles, are all of the same size and there is not this difference in the length of the degrees north and south. Knowing the length of a degree on a given circle, one can readily determine the distance in miles between two places on it by the difference in latitude or longitude.

150. Time on the Earth.—As the earth turns about in the sunlight, one-half is always illuminated and one-half always in shadow, but these are never stationary areas. Owing to the earth's motion, light and darkness follow each other around it at the rate of 15 degrees ($\frac{1}{24}$ of 360) an hour, or one degree every four minutes. To an observer on the earth, the sun appears to move from east to west at the same rate. When the sun is exactly overhead at a given place, it is noon at that place as well as at all other places on the same meridian. Fifteen degrees east of this meridian, it would be one hour later, and 15 degrees west, it would be one hour earlier. This is true *noon* by "sun time."

151. Time Belts.—In a great many places, true noon and the noon registered by the clocks and watches are not the same, the difference between them being often nearly an hour.

This is because man has agreed to a sort of artificial noon more suitable to his interests. Since the sun is steadily moving westward, true noon does the same, and if the sun time were used, the time at even nearby places would not be the same. To facilitate the running of trains and other work depending upon exact time, the surface of the earth has been divided into *time belts*, each 15 degrees wide, in which the clocks record time alike. When it is true noon over the center of such a time belt, it is assumed to be noon throughout the belt, though in some parts it is earlier and in others later than noon. There are five of these time belts in North America which, beginning in the east, are known respectively as *Intercolonial*, *Eastern*, *Central*, *Mountain* and *Pacific* time. Time, according to this arrangement, is known as *standard time*. The meridians that form the centers of the time belts are the 60th, 75th, 90th, 105th, and 120th west of the meridian of Greenwich. When a traveller passes from one time belt to another, he sets his watch forward or backward an hour, according to the direction in which he is traveling. Were it not for the time belts, his watch, on comparison with local time, would seem to be constantly gaining or losing time. The old abbreviations, a.m. for ante-meridian, and p.m. for post-meridian, have thus lost to some extent their significance since the adoption of standard time.

152. The Earth's Axis and the Zones.—The earth's axis is not at right angles to a line drawn from the sun to the earth, but is tilted $23\frac{1}{2}$ degrees from the perpendicular. In consequence of this, the north pole is inclined toward the sun during our summer season and away from it in winter. Exactly half of the earth is always toward the sun, but because of the tilted axis, the sunshine lacks $23\frac{1}{2}$ degrees of reaching the south pole in summer, while it shines $23\frac{1}{2}$ degrees beyond the north pole. In winter these conditions are reversed. Though first one pole and then the other is inclined toward

the sun, the position of the earth's axis does not change. It is the change in relative position as the earth travels around the sun, that causes this appearance, and also produces the changes in the seasons. When the sun and earth are in such positions that the sun is exactly overhead at the equator, its farthest rays just reach both poles. At this time, the days and nights are equal everywhere on the earth. This condition occurs twice every year, at the *vernal equinox* on March 21, when *spring* begins, and at the *autumnal equinox* on September 23, when *autumn* begins. In *spring*, the sun appears to pass north of the equator, and at the beginning of summer is $23\frac{1}{2}$ degrees north of it. Here it appears to stop and turn southward again. This point marks the *summer solstice*, at which time, in the Northern Hemisphere, the days are longer and the nights shorter than at any other time. The circle over which the sun appears to stop is called the Tropic of Cancer. At this time, the sun's rays lack $23\frac{1}{2}$ degrees of reaching the south pole and the circle which they touch is called the *Antarctic circle*. At the *winter solstice*, the sun is $23\frac{1}{2}$ degrees south of the equator over the Tropic of Capricorn, and its rays then just reach the *Arctic Circle* $23\frac{1}{2}$ degrees from the north pole (§80).

Practical Exercises

1. Does the size of the circle make any difference in the number of degrees in it?
2. How does the size of a circle affect the size of a degree?
3. What is the great circle called that is located midway between the poles of the earth?
4. In what part of the world is Greenwich, from whose meridian longitude is usually measured?

5. What is the number of the meridian on the opposite side of the world from Greenwich?

6. How does the length of a degree on any circle north or south of the equator compare with a degree on the equator? Why?

7. Draw a circle and divide it into 4 equal parts by lines running through its center. Where the lines cross, four right angles are formed. By means of a protractor, find how many degrees there are in a right angle.

8. Draw a line through your circle, making an angle of 45 degrees with a horizontal line.

9. Draw a circle to represent the earth and indicate by a line the axis tilted the proper number of degrees from the perpendicular.

10. What is the name of the zone bounded by the antarctic circle?

11. How many degrees are there from the equator to either pole?

12. How far north or south of the equator is the sun exactly overhead at some time of the year?

13. What zone do the tropics bound?

14. How many degrees wide is it?

15. How wide is each frigid zone?

16. How wide is each temperate zone?

17. If you go to a place where nothing obstructs the view, how many degrees will there be in your *horizon*?

18. How many degrees in a line drawn from one side of the horizon to the other through the *zenith*?
19. When the sun is overhead, how many degrees above the horizon is it at noon?
20. When the sun is perpendicular over the tropic of Capricorn, how high is it at the equator at noon?
21. The north pole points to the north star. How high would this star be if one were at the north pole.
22. If one should go south to the equator, where would the north star appear?
23. If you were in a part of the world where the north star was 60 degrees above the horizon, would you be nearer the equator or the pole?
24. When the sun is over the equator, how high is it in the sky in your region? What is your latitude?
25. How high is the sun at noon in your region at the beginning of winter? (Over what part of the earth is the sun perpendicular?)
26. How high in the sky is the sun at midsummer?
27. What time is it when the sun crosses the meridian on the opposite side of the earth from you?
28. How long is the longest period of daylight at the equator?
29. How does this compare with your own region?
30. What meridian determines the time for your locality?

31. When it is noon in your time belt, is it earlier or later than true noon in your own town?
32. Examine the globe for the *International Date-line*, where the day is assumed to begin. Near what meridian is it?
33. What advantage is there in having the day begin where it does?
34. Can you account for the irregularities noticed in the date line?
35. Suppose you were traveling around the earth toward the east. After you had gone fifteen degrees, would you see the sun an hour earlier or an hour later than in your first position.
36. Would you have lost or gained an hour?
37. What would be the gain or loss in going entirely around the earth?
38. Suppose you had gone around the earth toward the west. Would you have lost or gained a day?
39. The loss or gain of a day in going around the earth is adjusted at the international date-line by adding or dropping a day. If you should reach this line on the day before your birthday or other holiday, which way would you prefer to be traveling?
40. What would be the effect if you were traveling in the opposite direction?
41. Would this have any effect on your age?
42. Can you explain how it is possible for an event to happen on Monday in Japan and be known to us the Sunday before?
43. Why would a man at the north pole be unable to tell time by the sun?

CHAPTER XXVII

MACHINES

153. Mechanical Advantage.—A machine is a contrivance for transferring or transforming energy, and therefore can never give out more energy than is put into it. A “perpetual motion” machine is mechanically impossible. One of the advantages of a machine is that it can turn a small force applied for a long time at one point into a larger force for a short time at some other point, and thus a feeble force may be made to accomplish great things. By means of a strong bar, we may raise a stone that we could not move otherwise. It will be noted, however, that the stone moves only a few inches while the end of the bar to which the pressure is applied is moving much farther. That is, a small force acting through a foot or more has been transformed into a greater force acting through a few inches. The force applied to the machine is called the *effort*, or *power*, and the force the machine exerts is the *resistance* or *weight* overcome. The ratio of the resistance to the effort gives the mechanical advantage of the machine.

154. Simple Machines.—There are but six types of simple machines in the world. All more complex machines, whether watches, dynamos, steam engines, automobiles, or printing presses, are merely combinations of these simple machines which are so familiar to us that we scarcely think of them as machines at all. These simple machines are the *lever*, the *pulley*, the *wheel and axle*, the *inclined plane*, the *wedge*, and the *screw*. As a matter of fact, the principles upon which they operate may be further reduced to two—the lever and the inclined plane.

155. The Lever and Its Adaptations.—The lever is a rigid bar, straight or curved, which turns on an axis called a *fulcrum*. The divisions of the lever are called *arms*. If the arms of a lever are equal, a force applied to one arm will exactly balance an equal weight at the other. The balances in the chemical laboratory are of this kind. If the arms are unequal, however, it will be necessary to place a larger weight on the short arm to balance a given weight on the long arm. The old-fashioned steelyards and all platform scales are of this type. A general law of mechanics is that the power multiplied by its distance from the fulcrum is equal to the weight multiplied by its distance from the same point. Thus, 10 pounds on the arm of a lever 5 inches long will just balance a weight of 5 pounds on an arm 10 inches long. There are three classes of levers. In levers of the first class, the fulcrum is between the power and the weight, as in the balanced scales of the merchant. In levers of the second class, the weight is between the power and the fulcrum, as when we move an object by lifting on a bar the other end of which rests on the ground beneath it. In levers of the third class, the weight is at one end, the fulcrum at the other, and the power applied in the middle, as in the treadle of most foot-power machines. The wheel and axle may be considered as an adaptation of the lever—what might be called a lever arm revolving about a fulcrum. The mechanical advantage in this type of machine is found in the ratio that the circumference, the diameter, or the radius of the wheel bears to the circumference, diameter, or radius of the axle. Thus, if the diameter of a wheel is twice that of the axle, the force applied to the wheel will lift twice as much as if applied to the axle. The pulley may be considered another adaptation of the lever, the shaft on which the pulley is fixed being the fulcrum. The rope running over the pulley acts as a balance lever, since any force pulling down on one end will exactly balance an equal weight on the other. If

one end of a rope be fastened to a support, however, and then carried over a free pulley to which a weight is attached, a pull upward of 25 pounds will lift a 50-pound weight, but the rope will move twice as far as the weight is lifted. The power or effort necessary to move a given weight by the use of a pulley may therefore be diminished by introducing one or more free pulleys over which the rope runs. In other words the power is multiplied as many times as the rope passes over the movable pulley, or pulleys thus introduced. The distance through which the rope must move, however, is also multiplied in proportion to the distance traversed by the weight lifted.

156. The Inclined Plane and Its Adaptations.—The second type of the simple machine is the *inclined plane*. In this the mechanical advantage is the ratio of the length of the plane to its height. For instance, it will take only one-half as much effort to roll a barrel up a plane 8 feet long into a wagon 4 feet high, as it would to lift the barrel directly into the wagon, but though the force in this instance is only half as great, it travels twice as far. The *wedge* is a form of the inclined plane which is pushed under the load instead of the load being moved upon it. Its mechanical advantage is exactly like that of the inclined plane. The *screw* may be regarded as an inclined plane winding about a cylinder. The distance between any two adjoining threads is called the *pitch*. Screws when used as machines, usually work with a lever. The mechanical advantage in the screw is found to be the ratio of the distance traveled by the power (end of the lever) to the pitch of the screw. If the pitch is $\frac{1}{4}$ inch and the lever travels in a circle 3 feet in circumference, the ration would be 144 ($3 \times 12 \times 4$) to 1, and a force of 10 pounds applied on the lever would lift a weight of 1440 pounds on the screw.

157. The Hydraulic Press.—The hydraulic press is a machine by means of which a man is able to exert many

thousands of pounds pressure with what appears to be a very small effort. The machine consists essentially of two connecting cylinders of unequal diameters filled with water. When pressure is applied to the water in the small cylinder, it is transmitted to the large cylinder where it is multiplied as many times as the cross-sectional area of the large cylinder is greater than that of the smaller one. At the same time the general law of machines holds good, for the piston in the small cylinder moves as many times as far as the effort is multiplied.

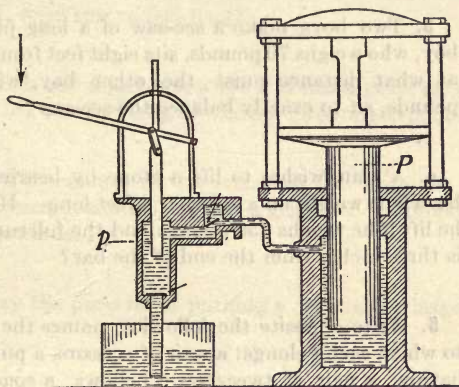


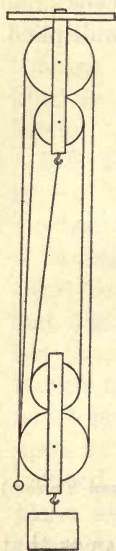
FIG. 64.—Cross-section of a hydraulic press. (*Tower, Smith and Turton.*)

Suppose a large cylinder to have an area of 1000 times that of the small one. Then one pound pressure in the small cylinder would give 1000 pounds pressure in the other, but the piston in moving the 1000 pounds one inch would have to travel a thousand inches. By making the pressure a hundred pounds in the small cylinder, it would have to travel 10 inches for each inch the thousand pounds was moved. Hydraulic presses are often used to compress coarse materials such as paper, shavings, cotton, and the like. Some elevators are also run by hydraulic pressure.

Practical Exercises

1. If a weight of 25 pounds be placed on one arm of a lever 10 inches long, how far from the fulcrum must a 10-pound weight be placed on the other arm to exactly balance it?

2. A meter stick has a fulcrum placed under it, exactly 20 centimeters from one end. On this end a weight of 100 grams is placed. How many grams must be placed on the other end to balance it?



3. Two boys make a see-saw of a long plank. If one boy, who weighs 70 pounds, sits eight feet from the fulcrum, at what distance must the other boy, who weighs 56 pounds, sit to exactly balance the see-saw?

4. A man wishes to lift a stone by bearing down with his whole weight on a crowbar 4 feet long. How much can he lift if he weighs 150 pounds and the fulcrum of his lever is three inches from the end of the bar?

5. Write opposite the following names the class of lever to which each belongs: a pair of scissors, a pump, a wheelbarrow, a pair of tweezers, a bellows, a spade, a door, a nut-cracker, a clawhammer.

6. A windlass with a crank 2 feet long is used to lift ore out of a mine. If an effort of 50 pounds is applied to the crank, how much ore can be lifted at a time if the lifting rope winds up on an axle 6 inches in diameter?

7. A bucket of water weighing 72 pounds is to be lifted by a windlass with an axle 6 inches in diameter and a crank 18 inches long? How much force must be applied continually to the crank to do the work?

8. Study the accompanying illustration and decide how many pounds pull on the rope will lift a 100-pound weight?

9. How far must the rope be pulled to lift the weight three feet?
10. How much force is needed to move a 200-pound load up an incline 1000 feet long and 50 feet high?
11. A man lifts a box weighing 100 pounds into a doorway 3 feet high. How much power would he have needed to move the box up an inclined board 6 feet long?
12. How much force would have been required if the board mentioned in question 11, were twelve feet long?
13. How much will a jack-screw lift if it has a pitch of $\frac{1}{2}$ inch and is operated by a bar two feet long to which a force of 100 pounds is applied?
14. Opposite the names in the following list write the name of the machine it represents: a chisel, an axe, a grindstone, a propeller, a wheelbarrow, an electric fan.
15. Why may the pressure of pushing a cork into a large bottle cause it to break?

CHAPTER XXVIII

MAGNETISM

158. The Lodestone.—Many centuries ago it was discovered that a certain kind of iron ore had the curious property of attracting other small pieces of iron. Ore of this kind is found in many parts of the world, and is commonly known as *magnetite*. If a piece of it be dipped into iron filings, they will cling to it, and tacks, small nails, and other small objects of iron or steel, may be picked up in this way. Pieces of this ore were once called *lodestones*, or leading stones, but since the first were found near Magnesia in Asia Minor, they have finally come to be called magnetic stones of natural *magnets*. A piece of steel, such as a knife blade or needle, may be mag-

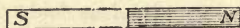


FIG. 66.—Magnets. (Tower, Smith and Turton.)

netized, or given magnetic properties, by stroking it with a natural magnet, and it will then have all the properties of the original magnet. *Artificial magnets*, made in other ways, are now very common and are indispensable in electrical work. In artificial magnets, the most common are *bar magnets*, made of straight pieces of steel, and *horseshoe magnets*, whose name is suggested by their shape. Steel, when magnetized, becomes a permanent magnet, but soft iron can be magnetized only temporarily. When a magnet is hammered, heated, or twisted, it loses its magnetism.

159. Poles of the Magnet.—If a lodestone be dipped into iron filings, it will be found that there are two places on its surface where the filings seem to be held with greater force than elsewhere, and this condition is also found to exist in all artificial magnets. When any magnet is hung up in such a way that it is free to turn in any direction, it soon assumes a general north and south position and, when pushed out of this position, it returns to it as soon as released. This shows that the position assumed is not accidental, and indicates the existence of some sort of force affecting it. The end of the magnet which thus invariably turns toward the north is called the north-seeking pole, or simply the *north pole*, while the opposite end is the *south pole*. On many magnets, the poles are indicated by the letters "N" and "S" stamped upon them. The poles of a magnet agree with the points on its surface which attract iron most strongly.

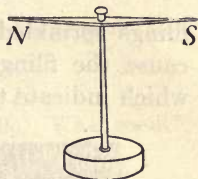


FIG. 67.—A magnetoscope. (Tower, Smith and Turton.)

160. The Earth a Magnet.—The earth itself appears to be a great magnet with one pole near the geographical north pole, and another in the southern hemisphere on the opposite side of the earth. It is to this magnetic north pole, rather than to the geographical north pole, that the magnet turns. This pole is west of Baffins Bay, but its position varies somewhat. In consequence, there are many places in the United States where magnets do not point due north and south if allowed to swing free. In surveying and other work depending on the use of the compass, allowance must therefore be made for this difference.

161. The Compass.—The compass is simply a magnetized needle so mounted as to move freely in a horizontal circle and thus indicate by its position the direction of the north magnetic pole. A true north and south line is then easy to establish by making proper allowance for the difference be-

tween the true north pole and the one toward which the needle points. A magnetized needle mounted to swing in a perpendicular circle is called a *dip-needle*.

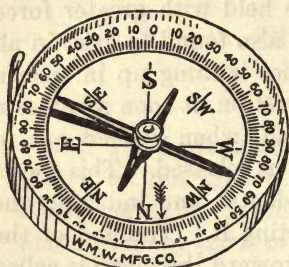


FIG. 68.—Compass.

When a dip-needle is carried toward the north magnetic pole, its north pole begins to dip downward and, at the pole, assumes a perpendicular position. The magnetic pole may therefore be located either by the dip-needle or the compass.

162. Lines of Force.—If a piece of paper be laid over a magnet and iron filings sprinkled upon it, a gentle tapping of the paper will cause the filings to arrange themselves in curious patterns, which indicate the *lines of force* proceeding from the magnet.

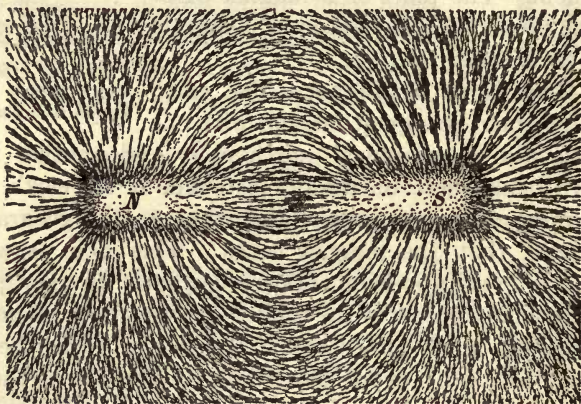


FIG. 69.—Iron filings showing lines of force about a bar magnet. (Tower, Smith and Turton.)

It will be seen that these lines tend to circle around from one pole to the other. The arrangement of the filings is due to the fact that each particle is for the time a magnet, and takes

the position that a compass needle would in the same situation. These invisible lines of force explain how a magnetic body may affect another without being brought into actual contact with it. As would be expected, the further apart such bodies are, the less will be the effect. When a body not naturally a magnet is given magnetic properties by contact with a magnet, it is said to be magnetized by *induction*.

Practical Exercises

1. Carefully place a sewing needle on the surface of a basin of water. Does it come to rest in any definite position? Make three trials.
2. Gradually bring one end of a bar magnet toward the needle. How does the latter behave?
3. Present the other end of the magnet to the needle. What result?
4. Magnetize the needle just used by stroking it several times in one direction with one end of the bar magnet. Place on the surface of a basin of water at some distance from any iron. In what position does the needle now come to rest? (Make several trials.)
5. Repeat experiments 2 and 3 with this needle. What is the result?
6. Slowly bring the north pole of a bar magnet toward the north pole of a compass. What is the result?
7. Repeat the foregoing experiment with the south pole of the magnet. Can magnets repel as well as attract?
8. Do like or unlike poles attract?
9. If we call the end of the magnet which points to the north the north pole, is the north magnetic pole a north or a south pole?

10. Dip a piece of soft iron rod or wire into some iron filings. Is soft iron magnetic?

11. Hold one end of a bar magnet against an iron rod and dip the opposite end of the rod in iron filings. How does the magnet affect the rod?

12. Remove the magnet. What effect has this on the magnetism in the rod?

13. If two bar magnets are to be kept in a box, how should they be placed with respect to each other?

14. An iron bar or pipe that has stood in an erect position for some time comes to have magnetic properties. By means of a compass, test such an object and discover which end is a north pole.

15. Sprinkle some iron filings on a sheet of paper or glass and slowly move a bar magnet beneath. Make the same experiment with the filings on a sheet of iron. Which of these substances is the best screen for magnetic action?

16. Which is the best test for a magnetized body, that it is attracted by a magnet or repelled? Why?

17. The Carnegie, a ship for making magnetic observations, is constructed without iron. Of what advantage is this?

18. Why would a compass be unreliable near a mountain of iron ore?

CHAPTER XXIX

STATIC ELECTRICITY

163. Electricity by Friction.—If a fountain pen, comb, or other object made of rubber, or an ebonite rod, be rubbed rapidly with a piece of woolen cloth such as a coat sleeve, the object will attract small bits of paper, shavings, and the like, exactly as a magnet picks up bits of iron and steel. A similar effect may be seen when a sheet of paper is warmed and rubbed

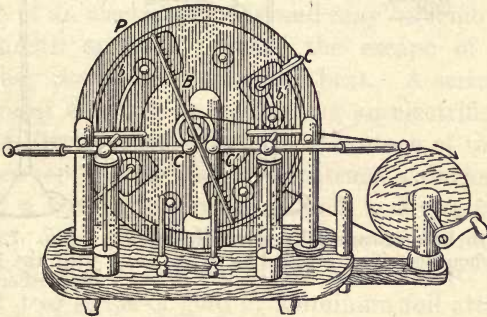


FIG. 70.—The Toeppler-Holtz induction machine. (*Tower, Smith and Turton.*)

vigorously with the hand or a woolen cloth. It will then attract other bits of paper, or cling to the wall or door if pressed against it. Sometimes the rubbing in this way may even produce a spark, as when one combs the hair with a rubber comb, or strokes a cat on a cold dry day. By scuffling about on a thick carpet, one may sometimes produce a spark large enough to light the gas when it is touched by the finger.

Bodies which behave in this way when rubbed are said to be *electrified* or *charged*. In many ways, magnetized and electrified bodies are alike, but they differ in one important particular. While almost any object may be electrified, only three common substances—iron, cobalt, and nickel—can be magnetized.

164. Two Kinds of Electricity.—When two bodies are electrified in the same manner, they act like similar poles of two different magnets—that is, they repel each other. This

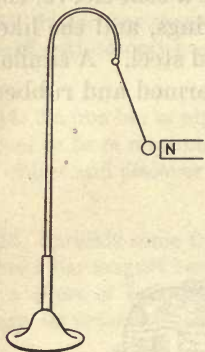


FIG. 71.—Pith ball attracted by electrified rod, but when electrified, repelled by it.

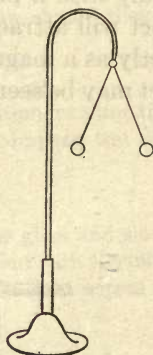
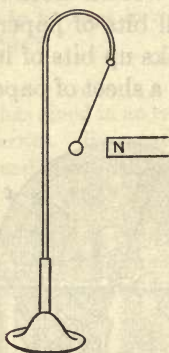


FIG. 72.—Pith balls with like charges repel each other.

can easily be shown by suspending tiny balls of cork, pith, or cotton by silk threads and testing them with some electrified object, such as a fountain pen or an ebonite rod rubbed with a woollen cloth. If the object is brought toward the ball before it is electrified, no change is noted, but when it is electrified the ball is first attracted by it and then as strongly repelled. If the same experiment be now performed with electricity obtained by rubbing a warm glass rod with a piece of silk, the balls behave as before, being first attracted by the rod and then repelled. But while two balls charged from

either an ebonite rod or a glass rod, repel each other, a ball charged from a glass rod will attract one charged from an ebonite rod. This shows clearly that there are two kinds of electricity, and that, as in magnetism, like charges repel and unlike charges attract. The electricity produced on glass is known as *positive* (+) electricity and that produced on rubber is *negative* (−) electricity. These two kinds of electricity appear to be so evenly balanced on all objects, that one cannot be produced without the other. When an ebonite rod is rubbed with a woolen cloth, for instance, negative electricity is developed on the rod, but positive electricity is developed on the cloth. It should be noted that, unlike magnetism, electrification is not more effective at one point on an object than another. It seems to be evenly distributed over the surface of an electrified body and may be removed at any point. Smooth surfaces prevent the escape of electricity much as they prevent the escape of heat. A series of points is always most effective in discharging an electrified body.

165. The Electroscope.—Taking advantage of the fact that like charges repel, it is easy to construct a device that will show when a body is electrified. Such a device is called an *electroscope*. Two pith balls attached to a common support by silk thread will serve the purpose, but the more usual form consists of two strips of gold or aluminum foil attached to a metal rod and enclosed in a glass flask to protect the delicate strips of foil. The rod is supported by a cork in the neck of the flask. When an electrified body is brought toward the electroscope, it becomes charged by *induction*, as it is called, and the strips of foil or the pith balls spread apart in consequence. When the electrified body is withdrawn, they fall together again. If, however, one touches the electroscope while the leaves are still separated, withdrawing the electrified body does not cause the leaves to fall together again, because one kind of electricity (the opposite of the one on the

charged body) has flowed away to the earth as soon as touched. There is left in the electroscope, therefore, only one kind of electricity which causes the strips of foil to repel one another, and until enough of the other kind of electricity can return to the electroscope and balance the charge it contains, the strips of foil must continue to be separated. This return of electricity is prevented by the glass case through which it can not pass.

166. Insulators.—Substances which, like glass, prevent the passage of electricity are called *insulators*. Glass is one of the best of insulators. Others are silk, amber, sulphur, rubber, and dry air. Metals and other good conductors of heat are also good conductors of electricity. Water is ordinarily a poor conductor, but when salts are dissolved in it, it becomes a good conductor. Substances that are ordinarily good insulators may become conductors when wet.

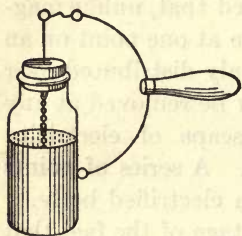


FIG. 34.—Leyden jar and discharger. (Tower, Smith and Turton.)

167. The Leyden Jar.—A glass jar with the lower half coated inside and out with tinfoil is known as a Leyden jar. A metal rod held in place by an insulator extends down inside of the jar and in contact with the lining. When the knob at the top of the metal rod is charged with positive electricity, it repels the positive electricity on the outside of the jar, which is at once conducted from the jar to the earth through the jar's support. After a time the jar becomes fully charged and will then receive no more electricity. It now has a charge of positive electricity on its inner surface and a like charge of negative electricity on its outer surface. If the two surfaces are then nearly connected by means of a wire, the jar is then discharged with a bright spark and crackling noise. Such jars and other similar structures are often known as *condensers*.

168. Lightning.—A lightning flash is simply a large spark similar to that produced by the discharge of the Leyden jar. When two clouds charged with electricity approach each other, they may act as the coats of a huge Leyden jar, the air between acting like the glass. When the charge breaks through the air from one cloud to another, a lightning flash is the result. Sometimes the earth and a cloud act as the two coats of a jar, and then we may have a stroke of lightning. Tall objects, such as chimneys, trees, and towers act as the wire did in discharging the Leyden jar, and are thus often said to attract the lightning. *Heat lightning*, often seen near the horizon on summer evenings, is simply the reflection of the lightning from thunder storms too distant for the thunder to be heard. The *Aurora Borealis*, or *northern lights*, is now regarded as being caused by the passage of electric currents far above the earth.

Practical Exercises

1. Why are electrical push buttons and switches usually made of rubber or gutta-percha?
2. The wires used for electric wiring in houses are covered with a layer of rubber or silk thread or by both. Of what use is this?
3. Does a charged body attract or repel one not charged?
4. Hang up two balls of pith or cotton by means of silk thread and charge from any convenient source. Thoroughly wet one of the silk threads and again charge. Which retains its charge best? Why?
5. Why could not wire be used as well as silk for suspending the pith balls?
6. When a large belt runs over a pulley, one may often draw a good-sized spark from it by merely touching it with a piece of metal. Explain.

7. In wet weather one may often get a shock by touching a tree with which an electric wire is in contact. Why is a shock not as likely on a dry day?

8. Is it possible for a lightning flash to move from the earth to a cloud instead of the reverse?

9. Why is a lightning stroke likely to run along a wire instead of taking a more direct path to the ground?

10. Why are the supports for electric wires made of glass or porcelain?

11. Why do electric linemen wear rubber gloves while at work?

12. If one had to move a naked wire known to be carrying electricity, which would be better to use, a glass or a metal rod?

13. Why is a cold dry day best for electric experiments?

14. Why will a Leyden jar fail to be charged if placed on glass?

15. Hold a piece of glass between the points of discharge on a friction electric machine. How do electricity and magnetism compare as to the ease with which they pass through glass?

16. Why should a lightning rod be "grounded" by being carried down to permanently moist soil?

CHAPTER XXX

CURRENT ELECTRICITY

169. Useful Electricity.—Static electricity, produced by rubbing one body with another, though important in some respects, is not capable of doing useful work. Even when it is accumulated on a condenser, such as a Leyden jar, the discharge is practically instantaneous, while for operating machinery and the like, a continuous flow of electricity is required. The current electricity now so extensively used, was not known until long after the effects produced by static electricity were familiar to scientists; but until its discovery, no progress in adapting electricity to manufacturing, transportation, and the like was possible.

170. The Voltaic Cell.—The first current electricity was produced by chemical energy. It was found that when a strip of copper and a strip of zinc were placed in a jar of water containing a small amount of sulphuric acid and their projecting ends connected by means of a wire, a weak current of electricity, produced by chemical reaction between the acid and zinc, would flow along the wire. Such an arrangement was called a Voltaic cell. Other metals and non-metals may be used in place of the strips of copper and zinc, and various other solutions may be substituted for the dilute sulphuric acid, but the result is the same in all, namely, the transformation of chemical energy into a current of electricity. Such cells are still used for supplying the current that rings door-bells and operates telegraph instruments, telephones, and the like. The most familiar form is the dry cell which consists of a zinc cup filled with moist chemicals surrounding a

carbon rod. The zinc cup takes the place of the zinc strip in the Voltaic cell, and the carbon rod takes the place of the copper.

171. Direction of the Current.—The two strips of metal in the Voltaic cell are called the *electrodes*, or poles, and the liquid in which they are placed, is the *electrolyte*. The zinc is called the *negative pole*, and the copper is the *positive pole*. The electric current is supposed always to flow from the positive to the negative pole in the current through the wire and from

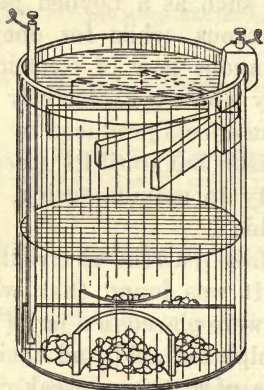


FIG. 74.—The gravity cell. (Tower, Smith and Turton.)

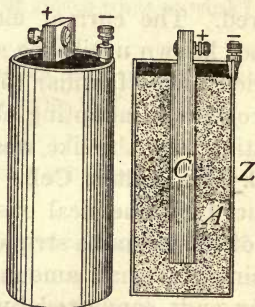


FIG. 75.—The Leclanché cell, "dry" type. (Tower, Smith and Turton.)

the zinc pole to the copper pole through the electrolyte to the starting point. So long as the two poles are connected, the current continues to flow and the circuit is said to be *closed*. If an electric bell be connected into the circuit it will ring, or an electric light may be made to glow. When the circuit is broken at any point, the current ceases.

172. Induced Currents.—Electricity produced by chemical means is too expensive for the thousand purposes to which electricity is now put. The current used for moving street

cars, elevators, railway trains, and other machinery is generated in another way. When a wire moves through a magnetic field, cutting the lines of force, a current is generated in the wire. The amount of this current depends upon the strength of the field, the speed of the wire, and the number of turns in the latter. The electric *dynamo* is a machine for revolving coils of wire in such a field. It is usually run by steam or water power. Our houses are lighted by currents of electricity induced by the powerful currents passing along the service wire, the induction taking place in the *transformer*.

173. Electroplating.—When a current of electricity is passed through a solution, it decomposes it by *electrolysis*. In this way, water may be decomposed into hydrogen and oxygen, and melted table salt decomposed into the metal sodium and chlorine gas. *Electroplating* is based on the same principle. The articles to be plated are attached to the positive pole of the battery and the piece of metal to be used in plating, either serves as the other pole or is attached to it. The electrolyte must also contain some of the metal. When the current is passed through the solution, small particles of the metal are carried across the solution and deposited on the articles to be plated. In this way, iron is “galvanized” with zinc or covered with tin, and brass and other metals plated with nickel, silver, or gold. In *electrotyping*, an impression of the type is taken in wax and a thin plating of copper is deposited on the wax, after which it is backed with type metal. Since wax is not a good conductor of electricity, the mould must be carefully dusted with powdered graphite before the work begins in order to make a connected circuit. Gold, copper, and silver are sometimes separated from their ores by electrolysis.

174. Electromagnets.—If a current of electricity be sent along a coiled wire, the wire acts like a natural magnet, and, if hung up and allowed to swing free, will assume a general north and south direction. By slipping into the coil a piece

of soft iron, called a *core*, the magnetic force of both coil and iron are greatly increased, and the effects continue as long as the current is flowing. When the current ceases, the iron is no longer magnetic. Magnets made in this way are called *electromagnets*. The most common form is of the familiar horseshoe shape. Such magnets are an essential part of our electric bells, annunciators, telephones, and telegraph instruments. Electric cranes, consisting of powerful electromagnets, are used for lifting heavy pieces of steel and iron in mills and factories. The electric bell is made to ring by

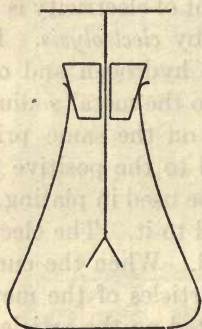


FIG. 76.—Diagram of an electrostatic induction experiment. (Tower, Smith and Turton.)

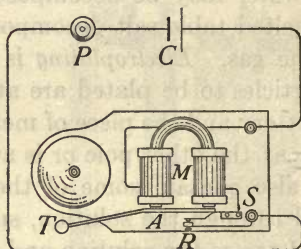


FIG. 77.—An electric bell and its circuit. A, Armature; M, electromagnet. (Tower, Smith and Turton.)

a device that alternately *makes* and *breaks* the current flowing through an electromagnet of horseshoe form. A piece of soft iron, called the *armature*, opposite the poles of the magnet is attached to the hammer of the bell, and, when not in action, a spring holds it away from the magnet and in contact with the wire from one pole of the cell or battery. When the circuit is closed, the current of electricity passes by way of the armature through the coils of wire in the horseshoe making it an electromagnet, and this at once attracts the armature and causes a stroke of the bell. The motion of the armature, however,

breaks the circuit, the magnet ceases to act, and the spring forces the armature back into its original position, where it again closes the circuit and causes the process to be repeated again and again.

175. Electric Light and Heat.—There is no substance known which will conduct electricity without offering some resistance to its passage. Good conductors, therefore, are simply those that offer the least resistance. The size of the conducting body also has an effect on the resistance, for the smaller

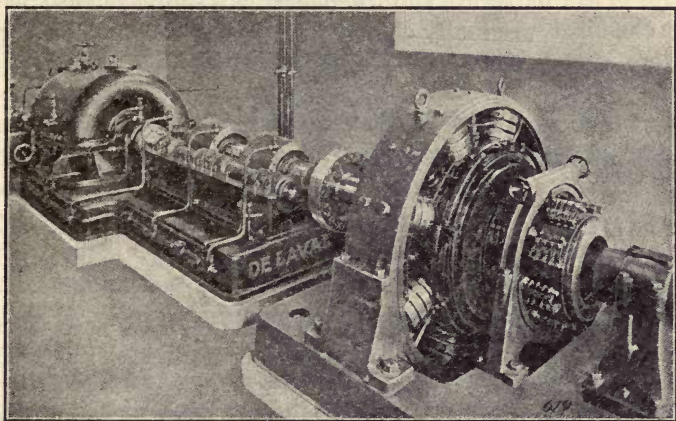


Fig. 78.—Electric generator.

the wire the greater the resistance. Since heat develops as the result of resistance, a smaller wire may be heated white hot by this means, as for example in the filament of the incandescent lamp. When it is attempted to send currents over wires too small to carry them, they may become so hot as to set fire to objects with which they are in contact. To protect buildings from this danger, a fuse or strip of metal is inserted in the circuit where it enters the building. Before enough current can be sent over the wires to overheat them,

the strip of metal melts and breaks the circuit. Electric flat-irons, toasters, and the like are heated by the resistance in the small wires which they contain. The mercury vapor lamps and lamps of similar structure give off light from the glowing vapor of mercury, nitrogen, or other gases.

176. Storage Batteries.—Storage batteries are not strictly places for storing electricity, but are devices by means of which electricity may be obtained as wanted. While being charged, the electricity changes the chemical composition of the contents of the batteries, and when used as a source of electricity, the chemicals gradually change back to the original form, giving up electric energy in the process.

Practical Exercises

1. How could you make a weak electromagnet stronger?
2. What would be the effect of using steel instead of soft iron for the cores of electromagnets?
3. What would be the effect of connecting the wires of an electric current by means of a glass rod? Why?
4. Why could not an alternating electric current be used for electroplating?
5. Why cannot a storage battery continue to take up electricity indefinitely?

CHAPTER XXXI

LIVING THINGS

177. Organic and Inorganic Bodies.—In the early days of science, philosophers regarded the universe as being made up of three groups or kingdoms containing the animals, the plants, and the minerals respectively. More extended study has shown that there are really only two kingdoms, the living or *organic*, containing all the animals and plants, and the non-living or *inorganic*, containing the rocks, minerals, air, water, and the rest of creation. Living things are composed of the same chemical elements that occur in other forms of matter, but they are sharply distinguished from them by being organized into forms of definite structure which, under the influence of a mysterious force called *life*, are capable of feeling, moving, growing or increasing in size, and reproducing or increasing in numbers. In living things, also, each part is dependent to a certain extent on the whole body, while in the non-living no such dependence exists. When a thing is alive, it is continually adding new matter to its substance, and as constantly discarding other matter no longer of use. Only living things can do this; in fact, when the adding process, or *assimilation*, and the discarding process, or *excretion* ceases, *death* ensues and the body ultimately returns again to the chemical elements from which it was made.

178. Cells.—The living parts of both animals and plants consist of a substance called *protoplasm* which is a semi-fluid much like the white of an egg in appearance. The smallest living unit of protoplasm is called a *protoplast* or *cell*. Such cells are much too small to be seen with the naked eye, but

they can readily be seen with a compound microscope and some of the larger ones may be distinguished with a good lens. A typical cell consists of a rather dense portion, called the *nucleus*, in which the life processes center, and a more fluid portion, the *cytoplasm*, surrounding it. In the cells of plants especially, there are one or more cavities, called *vacuoles*, in which the *cell sap* is found. Plant cells are usually surrounded by a thin membrane called a *cell wall*, which is built up by the protoplast, but animal cells seldom have these cell walls.

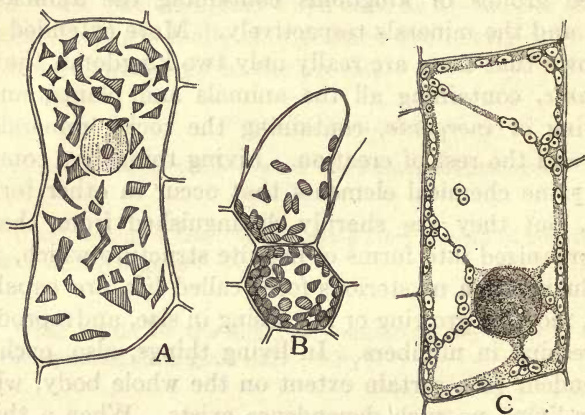


FIG. 79.—Cells and their contents. *A* and *B*, with red and yellow chromoplasts; *C* with nucleus and green chloroplasts. (*A*, after Strasburger; *B*, after Frank; *C*, after Stevens.)

The substances that cells build up are sometimes more conspicuous than the cells themselves, especially in the harder parts of animal bodies. The simplest animals and plants consist of single cells and, though so small, have all the essential capacities of living things. In more complex forms, there may be uncounted millions of cells, often varying greatly in shape. When similar cells are arranged in groups, they are called *tissues*. Pith, wood, cork, blood, muscle, and bone are tissues. The tissues are usually combined to form *organs*,

such as the stomachs of animals or the leaves of trees. It is the occurrence of these organs in all forms of life except the very lowest that causes us to name the group to which they belong the *organic kingdom*.

179. Growth.—In a sense, crystals may be said to grow in that they increase in size, but this increase is always from without by the addition of similar molecules. All living things grow by the addition of matter taken into their bodies and there built up into new molecules. In living things also there is a regular cycle of development. Beginning with a single cell, the organism increases in size by the repeated division of its cells until it reaches a determinate size and becomes *mature*. It then *reproduces*, or gives rise to new individuals, for a certain time, and finally declines to old age and ceases to exist. Of the two groups, the animals are more closely circumscribed both as regards length of life and size, but though some plants may continue to live for several centuries, there are certain limits as to their size beyond which they rarely pass. Animals again, usually have very definite shapes, though the simplest of them as well as the simplest plants are not thus restricted. Though the plant body, as a whole, has not as definite a form as has the animal body, some organs, such as flowers, fruits and seeds, are constant in this respect.

180. Food Making.—The material which living things build into their bodies and from which they obtain their necessary energy is called *food*. The food materials are the chemical elements in the soil and air, and plants are the only organisms in nature that can combine them into foods. In consequence, the entire animal world is dependent upon plants for its existence. The energy in food making is derived from sunlight by the green parts of plants. In these parts, the cells contain small green bodies called *chloroplasts* which stop some of the rays of light and change them into an available

form of energy. In the formation of ordinary foods, the plant uses the water from the soil and the carbon dioxide of the air. All the carbon found in plants is obtained in this way from carbon dioxide. Since only the carbon is used in food making, the oxygen is given off again by the plant. The process of making food in this way is known as *photosynthesis*. There are three classes of foods commonly formed by plants, namely, carbohydrates, fats or oils, and proteins. The carbohydrates are most common and are represented by such

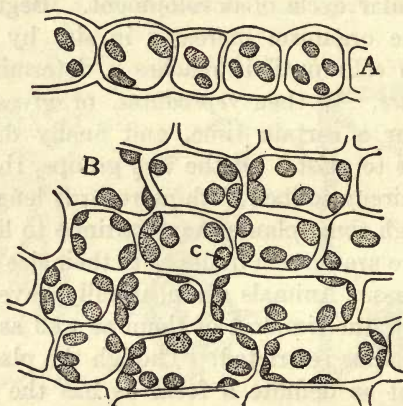


FIG. 80.—Sectional and surface view of part of moss leaf showing chloroplasts. (Stevens.)

substances as starch ($C_6H_{10}O_5$), grape sugar ($C_6H_{12}O_6$), cane sugar ($C_{12}H_{22}O_{11}$), and cellulose ($C_6H_{10}O_5$). In carbohydrates, the hydrogen present is always twice the amount of the oxygen. Most of the oils with which we are familiar are also produced by plants. These contain carbon, hydrogen, and oxygen, but the oxygen is usually in smaller proportions than in the carbohydrates. Proteins contain the three chemical elements found in other foods with the element nitrogen added. Protoplasm, lean meat, and albumen are examples of proteins. The bodies of all animals and plants, though

made of the same materials, differ considerably in composition. The animals have characteristically nitrogenous tissues, and the plants carbonaceous tissues.

181. Digestion.—The food stores of plants are usually in insoluble form, and have to be made soluble, or *digested*, before they can be built up into living tissues. Digestion is accomplished by the aid of certain ferments called *enzymes*, and requires the presence of a certain amount of water for their activities. The process is comparatively simple in plants, but in all but the simplest animals there are special organs for containing the food during the digestive process and various *glands* for secreting the enzymes and other digestive fluids needed. The digested food is carried in solution to the point in the body where it is used. In plants, the solution is commonly called sap; in animals, it is the blood.

182. Respiration.—One of our commonest sources of energy is the union of oxygen with carbon. In living things this is practically the only source of energy. Both animals and plants *respire*, taking in oxygen for the purpose, and giving out carbon dioxide. The real respiration occurs in the cells, but in animals there are usually organs for rapidly carrying oxygen to them. Plants, being less active than animals, respire more slowly, but the process is the same in all. From the fact that in photosynthesis plants take up carbon and give off oxygen, it is often assumed that the process of respiration or breathing in plants is exactly the opposite of that in animals, but this is a mistake. Plants respire like animals, but have in addition, the capacity for photosynthesis in which they take in carbon dioxide and give off oxygen. It is interesting to note that the formation and use of food is somewhat analogous to what goes on in the storage battery in that the energy from the sun, like the electric current, is made to produce certain changes in matter, and this energy is obtained again when the changes in matter are reversed.

183. Reproduction.—All living things must reproduce themselves, else their particular forms would soon cease to exist. In the simplest kinds, reproduction consists in the dividing of the cell into two equal parts each of which grows up and becomes a new individual. In higher forms, reproduction is a function of certain cells set apart for the purpose. These may divide into a number of small bits called *spores*, each of which is capable of producing a new individual, or they may form similar bodies which are unable to produce new individuals without uniting in pairs. Such uniting bodies are

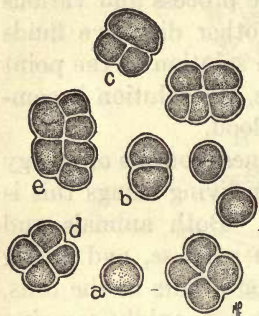


FIG. 81.—Cell division and the formation of a colony in green stain (*Pleurococcus*). (Gager.)

called *gametes*. In all the higher animals and plants, reproduction is by the union of gametes. When the uniting gametes differ in size, as they do in the higher kinds, the smaller one is called the *sperm* and the larger one the *egg*. Two sperms, however, cannot form a new organism, nor can two eggs. The union of a sperm and an egg is essential to the production of a new being in this way. With a difference in the size of the gametes, it becomes possible to indicate their *sex*.

The sperm is always called *male*, and the egg *female*. In most plants, and in the simpler animals, a single individual may produce both sperms and eggs, but in the higher animals each kind of gamete is produced by a separate individual which is therefore called male or female as the case may be. In plants, the organs of reproduction are found in a complicated structure called the *flower*. The eggs are produced in one or more bottle-shaped organs called *carpels*, occupying the center of the flower, and the sperms originate in certain cells, called *pollen grains*, produced by the pin-shaped organs or *stamens* surrounding the carpels. The transfer of

the pollen grains to the receptive parts of the carpels is called *pollination*. The colored parts of flowers, known as *sepals* and *petals*, protect the other organs and assist in the work of pollination by attracting bees and other insects which, in their efforts to get at the nectar, are forced to

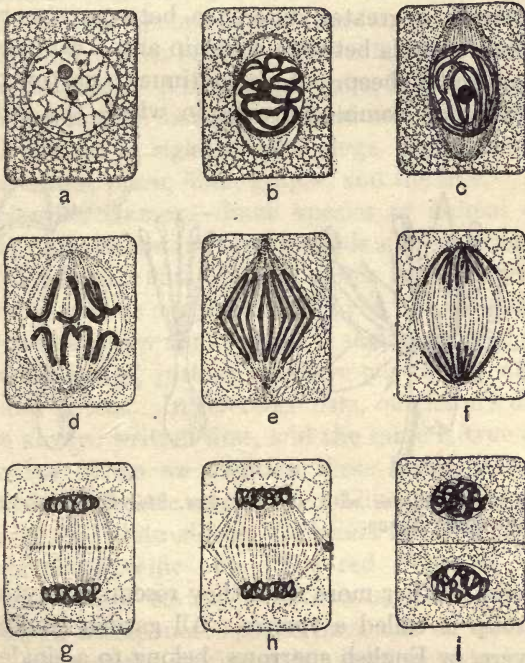


FIG. 82.—Semi-diagrammatic representation of nuclear division which occurs whenever a cell divides. (Stevens.)

brush against the stamens and so become dusted with pollen to be carried to other flowers. Flowers which lack petals and sepals are usually pollinated by the wind. In some species of plants, the stamens are borne on one plant and the carpels on another. Such species are said to be *diocious*.

When the stamens are borne on different parts of the same plant the species are *monœcious*. Most plants, however, have stamens and carpels in the same flower.

184. Species and Higher Groups.—The most careless observer must have noticed that the differences that separate one living thing from another are not always of the same magnitude. There is a greater difference between a cow and a cabbage than there is between a turnip and a cabbage, or between a cow and a sheep. If we continue to narrow our comparisons, we soon come to groups in which the individuals



FIG. 83.—A typical flower with all of the floral organs.

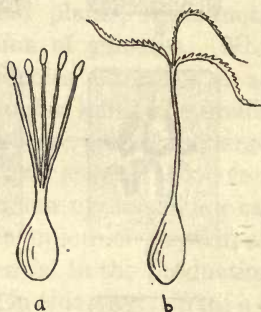


FIG. 84.—Compound carpels.

resemble one another more than they resemble anything else. Such a group is called a *species*. All garden sunflowers, or white clovers, or English sparrows, belong to a single species. We are well aware, however, that there are other kinds of sunflowers, clovers, and sparrows which resemble our typical species more than they do other plants or animals. It is, therefore, possible to arrange species which resemble one another into larger groups called *genera* (singular *genus*). In the same way we may assemble the genera into *families* and the families into *orders*. For instance, there are a number of

different species in the rose genus (*Rosa*), but they do not differ enough to be placed in different genera. When we examine the strawberry (*Fragaria*), the blackberry (*Rubus*), the bridal wreath (*Spiræa*), and a large number of others, we find the flowers are all of the typical rose pattern, but they differ enough to make it necessary to place them in different genera. We group all these genera in the rose family (*Rosaceæ*), and this great family, with several other related ones forms the rose order (*Rosales*). A similar grouping is found in animals. Many such groups in both the animal and plant worlds are recognized almost at sight as cats, dogs, deer, whales, mice, bats, bees, asters, pines, lilies, grapes, and the like.

185. Scientific Names.—Each species of animal or plant has its own name consisting of two words similar in significance to our own names. One of these words is the individual or *specific* name, such as our so-called “given” or christian name; the other is the group name which it shares with all the individuals in the genus, just as we share our family name with brothers and sisters. In reference lists, our family or generic names are always written first, and the same is true of plants and animals. When we mention these latter, however, we always speak the generic name first. Thus in *Trifolium repens*, the name of the white clover, *Trifolium* is the generic name and *repens* the specific one. The red clover is *Trifolium pratense*, the yellow clover, *Trifolium agrarium*, and so on. In addition to these, most species have one or more *common* or *vernacular* names. The question is often asked why one should use the *scientific* names when the common names are usually so much easier to pronounce, and the answer is that since the same species of plants and animals are often found in different countries, great confusion would ensue if the natives of each country used only the name current for it in his own tongue. The scientific names, derived mostly from the ancient Latin and Greek, are fixed in their meanings, and

by using them one may be understood wherever scientific men are found.

186. Distribution.—Evidences of organic life are everywhere present on the earth. The shallow waters teem with aquatic animals and plants, other forms creep or walk on the soil, or burrow into it, while still others are rooted in the soil. Other forms float in the air or move through it by their own efforts. The simplest living things are most widely distributed. They swarm in all soils and are to be found on mountain tops, in the arctic regions, and in the oceans depths. Inorganic substances on the globe are usually distributed in a haphazard way, but the distribution of living things depends so much on temperature, pressure, moisture, and light, that there are usually pretty definite limits to the *range* of each species. Oceans, deserts, mountain ranges, and extensive forests, frequently act as *barriers* to the spreading of a species in certain directions, and for this reason the plants or animals of distant lands are seldom identical, though the *flora* (plants) and *fauna* (animals) of the two regions may contain many related species. Living things are more or less adapted to the places in which they live, and cannot survive as well in any other, owing to the differences in temperature elevation and the like. A few may be adapted to other regions by making new adjustments to their surroundings. This is known as *acclimatization*. The flora and fauna change more rapidly as one travels north and south than they do if we travel east and west. The higher plants are unable to move about by their own efforts, as animals do, but the young plants in the *seeds* are usually provided with some means of locomotion by which they spread into new regions. Many seeds have tufts of hairs which serve as parachutes delaying their fall to the ground and thus carrying them to new places, others have winglike projections and are blown about by the wind, and still others are covered with a juicy pulp which ensures their being carried to new localities by birds and other animals.

187. Plant and Animal Forms.—While plants are less fixed as to form than animals, there are certain groups into which they are naturally divided on account of their structure or length of life. It is customary to group plants as *annuals*, which live but a single season, and *perennials* which may live for many seasons. The perennials are further divided into the *herbaceous* species which die down to the ground at the approach of cold or dry seasons, and the *woody* species which do not. The latter are further divided into the *trees* with a single woody stem, *shrubs* with several stems, and the *lianes* or *vines* whose stems, though woody, are much too weak to hold themselves erect and therefore climb on other plants. The animals, instead of being grouped according to length of life, as are the plants, are more frequently grouped into *Vertebrates* in which there is a spinal column, and *Invertebrates* in which this is lacking. The vertebrates contain the highest types such as the *fish*, *amphibians* (frogs, etc.), *reptiles*, *birds*, and *mammals*, but are greatly outnumbered by the invertebrates. The vertebrates never have more than four appendages for locomotion, and the highest division of them, the mammals, nourish their young with milk. The most noteworthy groups of invertebrates are the *Mollusca*, containing the snails, clams, oysters, and other "shell fish," and the *Arthropoda* which include the crabs, lobsters, spiders, and insects. All in this latter group have more or less distinctly jointed bodies, and from six to ten or more appendages for locomotion.

Practical Exercises

1. Strip a piece of fresh epidermis from an onion bulb, mount in a drop of water on a slip of glass and examine with a simple lens. The cells may be easily seen. (If a compound microscope is available, it will show the cell wall, cytoplasm and nucleus.)

2. Mount any of the green growths (algæ) found floating in ponds as directed in exercise 1 and examine. Note the colored bodies which function in food making.

3. Name as many species of oaks as you can.
4. Examine various kinds of flowers or consult the pictures in books and name all the members of the Leguminosæ (pea family) with which you are familiar.
5. The trailing arbutus (*Epigæa*) is called mayflower, ground laurel and ground ivy. What vernacular name do you use for it?
6. Which of the following names do you use for *Azalea nudiflora*: pinkster, azalea, mayflower, honeysuckle.
7. Following is a list of generic names. Make a list of those with which you are familiar. Are they the names of plants or animals? *Cosmos*, *Canna*, *Salvia*, *Zinnia*, *Magnolia*, *Chrysanthemum*, *Oxalis*, *Clematis*, *Iris*, *Phlox*, *Geranium*, *Viola*, *Lilium*.
8. Visit a piece of dry ground and a swamp. Are the plants alike on both places? Why?
9. Name an annual, an herbaceous perennial, a shrub, a tree and a liane with which you are familiar.
10. Make a list of ten invertebrates with which you are familiar.
11. Name the nearest barrier to the spread of plants in your region.
12. Does the barrier mentioned in the preceding exercise act equally well as a barrier to animals?
13. Name a plant with which you are familiar whose distribution in your region is limited by moisture.
14. Which seem able to grow best in a variety of situations, the weeds or the other wildflowers?
15. Examine various flowers and identify stamens and carpels. Which should be called male organs?

CHAPTER XXXII

EVOLUTION

188. **Origin of Living Things.**—From the earliest times, the great diversity of animal and plant life on the earth has attracted the attention of scientists and philosophers, and given rise to much speculation regarding the origin and subsequent development of the various forms. It was once thought that all forms of life were the objects of special creation, and that they appeared upon the earth at one time and in substantially the forms in which we now find them. Strong objections to this theory have arisen since exploration of the earth's crust has discovered the *fossil* remains of many forms quite unlike those of the present. These remains are not only found in the soil, but occur embedded in the solid rocks, showing that they must have existed even before some of the rocks were formed. These extinct animals and plants, though very different from present forms, bear certain well-defined resemblances to them, and the suggestion has often been made that some sort of relationship must connect them. The doctrine of special creation, however, dominated scientific thought almost universally until the last century, when an Englishman, Charles Darwin, wrote an epoch-making book on the "Origin of Species" which almost completely changed this view. In this book Darwin set forth with much skill a great deal of evidence to prove that the living things now on the earth have descended from these earlier and less highly specialized organisms through gradual changes during immense periods of time. Since the announcement of the *Darwinian Theory*, the accumulation of much additional evidence has only

served to strengthen the general proposition, though different phases of the subject have been modified in some respects as more facts have been discovered. It is still a question where the first life on the earth came from, but the idea that living things began as simple cells and that all the animals and plants have arisen from them by a succession of changes or *adaptations* is now commonly accepted. This latter conception of the origin of living things is known as *evolution*, and is strongly opposed to the theory of special creation.

189. Change in Nature.—Change is one of the most noticeable characteristics of nature. The seasons wax and wane, sunshine succeeds storm, day alternates with night, plants spring up and die, and even the solid earth itself is slowly changing through the ceaseless action of a variety of agencies. After a thunderstorm, every ditch and stream will be found carrying a heavy load of mud taken from the surface of the soil. It is very apparent, therefore, that the storms of a single year must have an appreciable effect in wearing down the elevations, and, if given sufficient time, this single agency might reduce the earth to a nearly level plain. There are, however, many other agencies aiding in the work. The oxygen of the air combines with various elements in the rocks and causes their decay. Carbon dioxide acts in the same way. Water, especially when containing acids from decaying vegetation, dissolves out the minerals, and running water containing sediment wears down the mountain valleys appreciably. Alternating heat and cold breaks up the rocks, water percolates into tiny crevices and freezing expands and widens them. The roots of plants add their mite toward turning the rocks into soil, and earthquakes and volcanos rend and change the solid rocks themselves. That the particles of the soil are really carried away is shown by the formation of mud banks or deltas at the mouths of great rivers, by the islands built up here and there in the streams, by filled lakes and river terraces,

and by the mud-covered ocean floor. The present appearance of the earth is only one stage in a long succession of changes; indeed, it is believed that the earth was once a body much hotter than the sun—a mass of incandescent gases in fact—and that it has reached its present shape through a cooling and shrinking process extending over such vast stretches of time that a million years is but a unit of measurement.

190. Organic Evolution.—It is very evident that the first plants and animals did not appear on the earth until some parts of it at least had cooled sufficiently to assume the solid state with a temperature not much higher than is found at the equator at present. That the earth had not reached its present form when such organisms appeared is shown by the fact that we find the remains of both animals and plants in all but the oldest rocks. Coal, as everybody knows, is composed of plant remains, and yet it is found everywhere deep in the earth where no plants could grow. Nearly every museum has a collection of fossil plants and animals taken from the rocks. The great changes in the earth which have undoubtedly taken place since the coal beds were formed must have sufficed to exterminate an immense number of species, genera, or even larger groups, but in the process making new *habitats* in which other races of animals and plants could exist.

191. Variation in Nature.—If we assume that the animals and plants of today have descended from earlier and less complex species by gradual changes in their form and structure, we shall find it necessary to show that living things are capable of making such changes. This, however, is not a difficult matter. No two objects in nature are exactly alike. Whether we are gathering flowers, choosing an apple, or selecting a kitten or puppy from among its brothers and sisters, there is always room for a choice because of the small dif-

ferences they present. This tendency toward variation which all organic life seems to possess makes it possible for some groups to outstrip others in the race for life. We can readily understand that in case a given species or race of animals or plants finds itself in surroundings where the conditions of life are growing increasingly difficult, the group whose variations are most favorable to their success is the group likely in the long run to survive. When an area becomes overpopulated, for instance, the race with the ability to quickly move into new regions and adjust itself to the conditions there, might not only survive, but originate new lines of descent.

192. The Struggle for Existence.—The fact which makes variation in animals and plants of much importance is the tendency which every species has to produce more young than can possibly come to maturity. A single fern leaf may produce several million spores in a season, and the plant may have several such leaves, while a single locality may contain thousands of fern plants. If every spore should grow into a new fern with spores of its own, and so on, it would only be a few years before there would be enough of this single species to thickly populate every square foot of the earth's surface. Such a thing is not likely to occur, however, because every other form of life is similarly attempting to conquer the world for itself. This can only result in a vigorous struggle for existence in which the strongest and best fitted to survive are practically the only ones that do so. In such a struggle, however, a fortunate variation may save a form from extinction by enabling it to overcome the forces opposed to it. When this phase of the subject is brought to his attention, the most casual observer will be able to recall evidences of such a struggle. Animals, as we know, constantly feed on plants, but the plants even up matters to some extent by feeding on animals, for the diseases that afflict animals, including man, are nearly all of plant origin. Plants struggle with plants,

and animals with animals, for food, and the more nearly related they happen to be, the fiercer the struggle, since the requirements of closely related species are very similar. There are also the effects of weather and climate to be considered. Frost, cold, and drought cause the death of many species annually. Many other circumstances have a bearing on the struggle, but in the end those forms best fitted to survive remain to reproduce their race, while others disappear. Thus the forms on the earth are the results of what might be called a *natural selection* in which the unfit are slowly weeded out and only the best preserved. If an organism happens to find itself in surroundings favorable to its development, its rapid increase in numbers is convincing testimony of the struggle it is under elsewhere. All the English sparrows in America are the progeny of a few pairs of birds brought to this country less than fifty years ago. Rabbits taken to Australia have overrun that country in a similar way. The prickly lettuce and Russian thistle have spread over the United States in the past half century. Many similar instances could be mentioned.

193. The Mutation Theory.—In recent years a Dutch botanist, Hugo DeVries, has suggested certain modifications of the Darwinian Theory based on a large amount of experimental evidence. These modifications are embodied in what is known as the *Mutation Theory*. The essential difference between the Darwinian Theory and the Mutation Theory is that the first assumes a gradual change from one species to another, while the second asserts that variation is not continuous but occurs by sudden leaps, as it were. One of the chief objections to the Darwinian Theory was that the “missing links” supposed to connect one species with another could never be found. The Mutation Theory accounts for the absence of such connecting links by the statement that they never existed, and that each new form springs practically complete from some nearly related one. This theory best

accounts for the appearance of a large number of *sports* such as white flowers among red-flowered plants, yellow fruits on plants that normally have red ones, and an immense number of other variations of this kind. If the different connecting links assumed by the Darwinian Theory really did exist, we should be unable to distinguish either species or genera. But while it is becoming increasingly apparent that the Mutation Theory will explain most of the puzzles connected with the origin of animals and plants, there is still a possibility that a goodly number of forms may have arisen by gradual change, as suggested by the Darwinian Theory, especially in those groups most closely linked together.

194. Elementary Species.—The older naturalists, while admitting the origin of living things through evolution, regarded the species once formed as something fixed and unvarying, but the Mutation Theory has shown that such species are probably a composite of a number of less conspicuous forms which are known as *elementary species*. These are what we commonly call *varieties*. Several plants are known that rather constantly produce such elementary species or “*mutants*,” and it is probable that other species may be made to do so. When a mutant is produced that is better adapted to its surroundings than the species from which it came, it may ultimately supplant the parent form in the locality; otherwise it is soon swamped by the multitudes of the ordinary form. If protected from extinction by cultivation, it may prove to be much superior to the original form. The different varieties of apples may be regarded as elementary species. All apples belong to a single species of apple, yet each possesses characteristics of its own which make it easily recognized by the student.

195. Plant and Animal Breeding.—Nearly all the plants used by man are superior to the plants of the same species found in the wild condition. In some cases our improved

varieties are so different from the original forms that the two are scarcely recognized as belonging to the same species. For instance, the prickly lettuce, a common weed of waste ground, is the parent of the garden lettuce. The same condition exists with regard to the animals, though plants, being less highly organized and yielding more readily to experiment, probably show the most remarkable results. In producing these forms man has followed nature's methods in selecting those most suited to his purpose. What man considers best, however, may not be the best from nature's standpoint, and are possibly not fitted to survive in a struggle with their environment, but under man's protection this is no obstacle to continued existence. A large number of our cultivated plants must be protected from the weeds by cultivation. Domestic animals must be protected in like manner from their foes. *Selection*, however, is only one phase of breeding. In plants especially, *hybridizing* or the union of the sperms and eggs of different species or varieties, is frequently utilized. Sports of all kinds are of value in affording a point from which to begin experiments. In order to induce a species to sport, variations of the food, temperature, and other characteristics of the surroundings are often made. In the early history of breeding the forms to be propagated were selected more or less arbitrarily, but with the discovery of *Mendel's Law* of inheritance, the work of breeding now proceeds upon more scientific lines. Mendel's discovery consists essentially in the recognition of the fact that the gametes—eggs and sperms—of a pure organism carry only the characteristics of that organism, and when the gametes of two different forms are united, these characters may be rearranged in new combinations with great accuracy. With these facts clearly understood, it becomes possible, by crossing plants or animals in different ways, to obtain rapid improvement in the species selected and thus produce many new and promising forms.

Practical Exercises.

1. Make a list of the fossil animals and plants that you have seen.
2. If there are any fossils in the rocks of your region, describe them.
3. Are the specimens mentioned in exercise 2 of animal or vegetable origin?
4. Name a place in your region that is being built up by the action of water.
5. Name a place in your region that is being torn down by water.
6. After the next rain find places in the nearest field to illustrate the actions mentioned in exercises 4 and 5.
7. Try to find two leaves exactly alike.
8. Examine mulberry and sassafras trees or Boston ivy for leaves of different shape. How do these differ?
9. Which can move into a new region quickest, a sparrow, a toad or a squirrel?
10. Which can move into a new region quickest, dandelions, burdocks or hickory trees?
11. Examine any open weedy place for examples of a struggle for existence. Is the struggle for water, light, food or sufficient room?
12. Examine the nearest flowery field for examples of variation. In what does the variation consist, color, size, shape or number of parts?

CHAPTER XXXIII

BACTERIA

196. Nature of Bacteria.—Bacteria, often called germs, are the smallest of living things. They can be seen only with the highest powers of the compound microscope and some are so small that fifty thousand in single file would not make a line more than an inch long. Bacteria are really plants, their nearest relations being the seaweeds, mushrooms, puffballs, and yeasts, but they are much smaller than any of these. Each consists of a single cell, the shape of which varies with the species. All, however, resemble certain types enough to enable us to classify them as round, rod-shaped, and twisted or corkscrew-like forms. Bacteria occur almost everywhere; in the air we breathe, in the water we drink, in the food we eat, in the soil underfoot, and even in the bodies of plants and animals. They multiply very rapidly by cell division and in some cases may double their numbers every half hour. It is due to their activities that wood rots, food ferments, and cider turns to vinegar.

197. Helpful and Harmful Species.—Although the bacteria are plants, they lack the green coloring matter of ordinary plants and thus are unable to make food for themselves. Like the animals, they require food already made, and this they take from the bodies of plants and animals, living or dead. As to the manner in which food is obtained, they are divided into two classes, the *parasites*, which obtain their food from living things, and the *saprophytes*, which feed only upon dead organic matter. In using the food, they act like other living things, breaking it down into simpler substances. In

this way they usually destroy any tissue they attack. Nearly all the diseases of animals and plants are due to the activities of bacteria. On the other hand, there are many helpful forms of these plants. Certain kinds give the flavor to butter, cheese, and tobacco, others turn cider to vinegar, and still others cause milk to sour. The retting of flax, by means of which the fibers for linen thread are obtained, is also due to the action of bacteria. Though the bacteria of decay often injure substances which we value, it is probable that even these must be placed among the helpful forms. To realize the helpfulness of such forms, we have only to consider what would happen if all the dead leaves and other refuse which falls on the earth were to lie where they fell without decaying.



FIG. 85.—Various forms of bacteria. (Gager.)

Moreover, there are a number of other forms in the soil which steadily break up organic compounds into simpler substances which the plants can use. Others, in connection with the group of flowering plants called legumes, add to the soil in available form nitrogen obtained from the air.

198. Toxins and Ptomaines.—Bacteria are of the highest interest to man because of the capacity for harm which certain species possess if allowed to thrive unchecked. When growing in protein foods, they may form poisonous substances called *ptomaines* which are very difficult to neutralize. Cooking the food may kill the bacteria, but it does not destroy the *ptomaines*. Other forms may secure entrance into the human body through the air passages, the alimentary canal, or through breaks in the skin due to abrasions or insect bites, and so cause

disease. Several diseases are now known that are communicated to man and other animals solely through the bites of insects. In the body, bacteria may break down the cells, or they may produce substances, known as *toxins* which rapidly poison it. In some cases, a colony of bacteria in a limited part of the body may produce toxins so deadly as to cause death in a short time.

199. Antitoxins.—In most cases, when a body is being poisoned by toxins, the cells form *antitoxins* to counteract them. The antitoxins kill the bacteria and so free the body from their effects. The white corpuscles of the blood also rapidly destroy bacteria. Were it not that the body is protected in this way, even slight injuries would prove fatal. In some cases, the body does not produce its antitoxin fast enough and is helped in its work by the injection of similar antitoxins taken from other animals. The antitoxin used in diphtheria is of this nature. There are a number of bacterial diseases which we usually have only once, the effects of the antitoxins made during the course of the disease seeming to protect the body from other attacks of it through life. The individual is then said to be *immune* to that disease. In other diseases, the effects fail after a time and the disease may then be taken again. A number of *serums* which are practically antitoxins have been discovered in recent years and used for the cure of disease. These are made from the blood of other animals attacked by the disease or, in some cases, from the bacteria themselves.

200. Disinfectants and Antiseptics.—Since bacteria are plants, they may be destroyed by the same agencies that kill other plants. Drying stops the activities of all but does not kill many kinds. They simply go into a resting condition and revive when more moisture is found. Exposure to sunlight kills many species and exposure to extreme cold, like drying, retards their activities and in many cases kills them. The

surest way of destroying bacteria, however, is to subject them to great heat, either by boiling or steaming them. Even temperatures much below the boiling point have been found to be effective in the case of many kinds. Milk is pasteurized by being brought to a temperature of 130°F. and held at that temperature for a few minutes. Bacteria are also rapidly destroyed if exposed to the ultra-violet rays, and chemicals of various kinds are also effective. Rendering objects free from bacteria is called *sterilizing*. Chemicals used in killing bacteria are usually called *disinfectants*. In the human body, however, the problem of destroying bacteria is complicated by the necessity of killing the bacteria without injuring the cells. Substances which will accomplish this are usually called *antiseptics*. Among substances used externally for such purposes are tincture of iodine, boracic acid, carbolic acid, hydrogen peroxide, bi-chloride of mercury, and alcohol. Salt, sugar, and other substances, by extracting the water from bacteria, affect them somewhat as ordinary drying does. Such substances are often called *preservatives*.

Practical Exercises

1. Give a reason for washing the hands before eating.
2. Why is it desirable to wash thoroughly food that has been exposed for sale in the open market?
3. Why are cooked foods likely to be more wholesome than raw foods?
4. Why might tea or coffee made from a suspected water be less dangerous than the water itself?
5. Why should refrigerators and other receptacles for food be frequently cleaned?

6. In preserving food from decay, what advantage is taken of the fact that plants need moisture for growth?

7. In canning foods, why is it necessary to bring the materials to a high temperature?

8. Why is it customary to seal the cans containing such food?

9. Canned foods may be preserved from decay if, while still hot, the jars containing them are closed with a wad of cotton. Explain.

10. In preserving foods from decay, what advantage is taken of the fact that plants need warmth for growth?

11. Why do canned foods soon spoil if exposed to the air?

12. Why are damp rooms undesirable as residences?

13. Why are cellars and other poorly lighted places undesirable for residences?

14. Of what use is it to expose bedding to the sunlight?

15. Why is it desirable to avoid contact or association with persons who are suffering with disease?

16. Why are manufacturers forbidden to use certain kinds of chemicals for preserving foods?

17. Make a list of the antitoxins of which you have heard.

18. Make a list of the disinfectants with which you are familiar and check those which may be used as antiseptics.

19. Why is it desirable to avoid the bites of mosquitos, lice, fleas and the like?

20. The common house-fly does not bite. Why screen it from our homes?

21. Why are dusty places undesirable for residences?

CHAPTER XXXIV

THE FRAMEWORK OF THE BODY

201. The Skeleton.—From the fact that the simplest animals have no skeleton, we perceive that the possession of such a structure is not an essential characteristic of animal life, though, since all the higher types possess something of the kind, it apparently plays a part of some importance in the animal body. The first skeletons were external and were represented by such structures as the shell of the clam, the hard outer parts of the lobster and crayfish, and the horny covering of beetles and other insects. An internal skeleton is found only in the group called vertebrates, and it is only in this group that true bones occur. Man being the highest representative of this latter group, of course, has one of the most highly developed of skeletons.

202. Arrangement of the Skeleton.—The skeleton serves as the framework of the body, somewhat analogous to the wood and bast of plants. Its chief function is to form attachments for the muscles and thus to aid in producing motion, though it also serves to give shape and strength to the body and to protect the more delicate organs. A fundamental pattern may be seen in the skeletons of all vertebrates, though variously modified to meet individual needs. There is first of all an axis consisting of a number of joints or *vertebræ* which we commonly call the *spine* or *back bone*. In man there are thirty-three of these *vertebræ*, though in adult life the last nine are fused together into what appear to be two bones. In the lower animals, these bones, often with others, form the tail. At the opposite end of the axis are twenty-two irregular

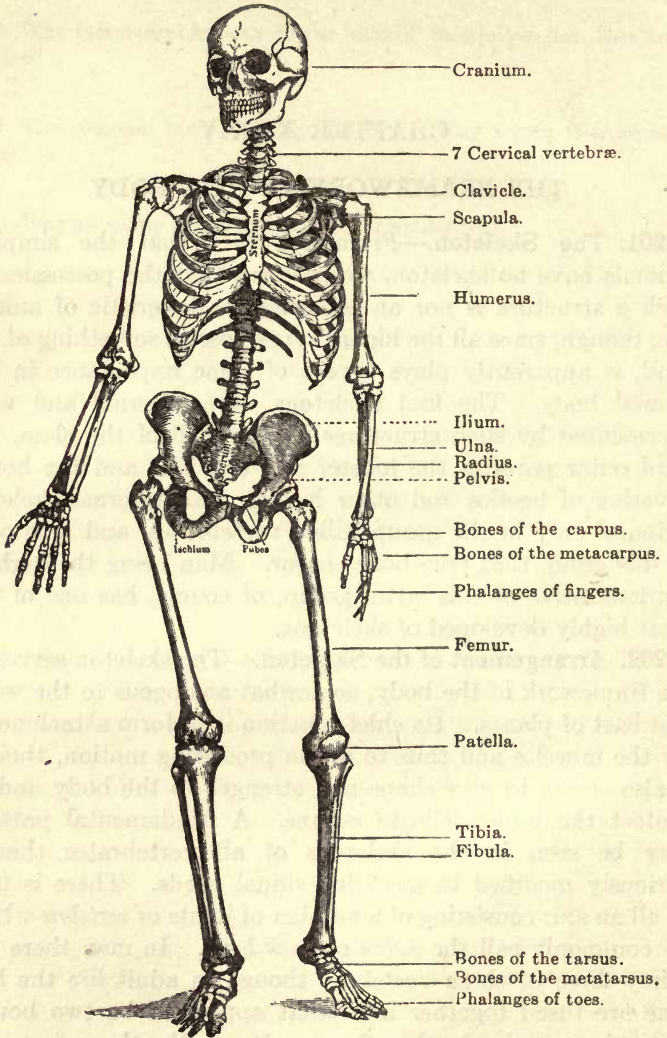


FIG. 86.—The skeleton. (After Holden.)

bones forming the *skull* or framework of the head in which the organs of special sense are located. In man the bones of the spinal column are arranged in a slight double curve and the column itself is erect. In the lower animals the spinal column is usually parallel with the earth's surface. The part which includes the head and, in all vertebrates, goes first, is called the *anterior* portion and the opposite part is the *posterior*. The upper side is the *dorsal* surface and the under side the *ventral* surface. Attached to the axis are usually two girdles of bones each bearing a pair of appendages or limbs. In man these appendages are called *arms* and *legs*. Between the two girdles are also attached in pairs a number of curved bones or *ribs*. Man has twelve pairs of ribs, all of which, excepting the last two pairs, are also attached in front to the *breast-bone*, which is really three bones in one. These bones thus form a sort of bony cage in which are the heart and lungs. The longest bones of the body are found in the appendages. These long bones are nearly cylindrical, hollow and filled with a fatty marrow in which the red blood corpuscles are formed. The flat bones, such as the ribs and the bones of the skull, have no central cavity. The ends of the bones are pitted and ridged for the attachment of the muscles, and the vertebræ have various bony projections for this purpose. The bones are derived from cells so small that one wonders how they can form a substance so strong as bone: the same may be said of the teeth. The bones of all young animals are very soft and flexible at birth but grow harder with age. This explains why a child may escape without broken bones from a blow that would seriously injure an adult.

203. Joints.—The bones of the skeleton are joined together in a variety of ways. Those of the *cranium* (that part of the skull that encloses the brain) are closely and immovably joined. Such joints are usually called *sutures*. Other joints are constructed on the familiar hinge pattern, allowing con-

siderable motion in one plane; still others are able to slide over one another for a short distance. When more extended movement is required, the ball-and-socket joint may be found, as at the shoulder and hip. In the elbow and wrist, there is a sort of rolling joint which enables us to turn our palms outward. The head is mounted on the apex of the spinal column by a sort of rocking joint and the vertebra supporting the head turns part way around on a pivot. Great freedom of motion is possible at the shoulder from the fact that the pectoral girdle is attached only indirectly to the axis. Strips of cartilage attach the ribs to the breast bone and thus permit the chest to be expanded in breathing.

204. Muscles, Tendons and Ligaments.—The parts of the skeleton are held together by stout ligaments and the moveable joints are padded with a firm substance called *cartilage*. All of the spinal vertebræ are separated by pads of this substance. The *muscles* and *tendons* also aid in holding the skeleton together, but their chief use is to produce motion. In animals used for food, we recognize the muscles as lean meat and the tendons, ligaments, and cartilage as gristle. A good example of cartilage may be found in the hard parts of the outer ear or at the tip of the nose. The soft and tender muscle cells are bound up in small bundles by a substance called *connective tissue* and these bundles combined into larger aggregations form the muscles. In a tough piece of steak, the whitish fibers running through it are sections of connective tissue. Toward the ends of the muscle the strands of connective tissue join together forming the stout and glistening white tendons by means of which the pull of the muscles is carried across the joints. In moving the body, the bones and muscles act much like the ropes and arms of a derrick. Each end of a muscle is attached to a different bone and thus when the muscle contracts and shortens, motion of one bone or the other is produced. It is the simultaneous contraction

of all the muscle fibers that causes the muscle to shorten. The tendons themselves are not elastic. There are nearly 300 skeletal muscles in the body and they occur almost invariably in pairs, thus acting as antagonists to each other. One pulls a bone in one direction and the other returns it to its original position. Most muscles end in tendons, but all do not do so. The *diaphragm*, one of the most important muscles in the body, is such an exception. It is located just below the heart and lungs and separates the body cavity into two chambers called respectively the abdominal and thoracic cavities. Certain other muscles are designed to regulate the size of various tubes and openings and are known as *sphincters*. Such a muscle is found where the stomach opens into the intestine.

205. Value of Exercise.—In order to contract, a muscle must receive a stimulus from the brain. When a stimulus thus causes a muscle to contract, it remains in that condition for about $\frac{1}{10}$ of a second. A longer period of contraction requires additional stimuli. When a muscle is used continuously for a time it becomes fatigued and rest is necessary. A change of work which puts other muscles into action may serve the same purpose as a complete rest. Regular exercise is beneficial to the muscles since it educates the cells to work in harmony and promotes their development. Muscles which are used regularly are larger, firmer, and darker colored than those which are not so used. In developing the muscles, a little exercise each day is much better than more vigorous exercise at irregular intervals. Rowing, swimming, walking, and running are desirable forms of exercise because they call so many muscles into action. Many forms of exercise are taken for the pleasure they give, such as walking, dancing, skating, and many of the games played by children.

206. Breaks, Sprains and Deformities.—When a bone is broken, it must be held immovably in one position until the bone cells can form new matter with which to knit the broken

ends together. To facilitate this, the injured member is usually bound with splints or enclosed in a plaster cast. When the break is a slanting one, the tension of the muscles may cause one part of the bone to be drawn past the other, in which case it may be necessary to use a weight to hold the ends apart and prevent the bone from being shorter when repaired. In *sprains*, the ligaments are loosened, strained, or torn from their fastenings, and, since such injuries heal very slowly, sprains often prove as serious as broken bones. The best remedy for a serious sprain is rest, but as recovery is made, the part should be given gradual use to prevent its becoming stiffened. When bones are driven from their proper positions at the joints, they are said to be *dislocated*. In youth, the parts of the skeleton, being less rigid than in later life, are easily bent out of shape and this may result in permanent deformities. Among the most common of deformities are *bow-legs*, *round shoulders*, and *crooked spines*. Children may be made bow-legged by being encouraged to walk before the bones are strong enough to support their weight. Round shoulders are often caused by bending over a book or other work for too long a time or by sitting at desks that are too low. Crooked spines result from sitting in improper positions. One should not sit too long in one position and when standing should maintain an erect carriage. If one will remember to "stand tall," that is, to stretch up to the full height, much will have been done to avoid an awkward carriage. Tight clothing over the ribs may cause deformities which are harmful because they interfere with correct breathing, and tight shoes may result in bunions, enlarged joints, and the like. High heels are especially to be avoided since they throw the weight of the body on the ankles in such a way as to make them thick and clumsy, and this improper distribution of the weight may also cause broken arches, which result in flat feet.

Practical Exercises

1. How many joints in each of the four appendages of the human skeleton?
2. How many bones in the arm (from shoulder to elbow)? How many in the forearm (from elbow to wrist)?
3. Which of the digits (fingers and toes) have one division less than the others?
4. Which section of the lower limb corresponds to the arm?
5. How does the number of bones in the forearm compare with the corresponding part in the lower limb?
6. What difference do you notice in the direction in which the elbow and knee bend?
7. Clasp the arm above the elbow and bring the forearm up to the shoulder. What change in size do you notice?
8. How many tendons can you feel on the inside of the elbow joint while bending it?
9. How many tendons can you feel under the knee when it is bent?
10. How many tendons just above the heel?
11. Can the ribs move?
12. Which has the greater freedom of movement, the wrist or the ankle? Why?
13. Name the kind of joint illustrated by the following: shoulder knee, wrist, knuckles.

14. In the lower or pelvic girdle, there are two bones called the pelvic or hip bones. How many bones in the pectoral girdle (at the shoulder)?
15. What appendages in the bird correspond to the human arm?
16. How do the bones in the arm and forearm compare in number with the bones in the corresponding parts of a bird?
17. What vertebrate animals lack an appendicular skeleton?
18. Which has the greater freedom of motion, the thumb or the great toe?
19. Of what advantage is this?
20. Examine the arm and forearm and locate the muscles that open and close the hand.
21. Where are the tendons located that transmit this motion?
22. Why are the bones of the lower extremities larger than those of the upper?
23. Which are larger, the vertebræ near the head or those near the hips? Why?
24. Why may large pillows be injurious?
25. The muscles on the breast of a pigeon are dark and those on the breast of a chicken are light. Why?
26. Why does merely standing up become tiresome?
27. Which is less tiresome, a long walk in hilly country or the same distance on a level? Why?

CHAPTER XXXV

THE GOVERNOR OF THE BODY

207. Need of a Governor.—The power of motion is inherent in all protoplasm, but when this protoplasm is arranged in tissues consisting of millions of cells, it is impossible to conceive of their working in harmony without some kind of a directing force. In addition, there must be a *motor* impulse to cause the cells to work at all. Moreover, since the motor impulse comes from within, there must be some means of carrying *sensations* from the outside. The part of the body charged with this task of direction is the nervous system, which consists of the brain, the spinal cord, the nerves, and the end organs. The principal parts of this system are carefully preserved from injury. The *brain* is enclosed in a bony box, the *cranium*, which forms part of the skull, and is protected by three membranes; the *spinal* cord runs down through a series of bony arches formed by backward projections of the vertebræ and the large *nerves* are deep in the flesh, close to the bones, with only their finer divisions coming to the surface. There are twelve pairs of these nerves given off by the brain and thirty-one given off by the spinal cord. Each consists of a tract over which sensations travel to the brain and a tract over which motor impulses travel from the brain to the muscles, glands, and other end organs. These impulses are similar to electricity in their manifestations and travel along the nerves at the rate of more than 100 feet a second. New impressions may originate in the brain and be carried out by impulses sent to the cells in various parts of the body, but usually some disturbance from outside stimulates the sensitive

nerve endings and a sensation is carried to the brain which results in some kind of motor impulse being sent to the muscles or other organs.

208. The Brain.—The upper and forward part of the brain is known as the *cerebrum*. It is here that impulses involving intelligence, memory, the emotions, and the will originate. The cerebrum is divided by a deep groove into a right and left hemisphere and consists of white and gray matter, with the gray matter, which is made up of nerve cells, on the outside. Below and back of the cerebrum is the *cerebellum* or little brain, whose chief function is to coördinate the action of the muscles and cause them to coöperate properly in carrying out the directions of the cerebrum. Below the cerebellum, where the spinal cord connects with the brain, is an enlarged portion, the *bulb* or *medulla oblongata*. This part, in addition to other functions, controls the beating of the heart, breathing, digestion, secretion, and other processes not directly under control of the will.

209. The Spinal Cord.—The spinal cord extends down along the spinal column and, like the other parts of the brain, consists of gray and white matter, though in this instance their positions are reversed, the white matter being on the outside. The white matter is the part over which nervous impulses travel to and from the brain, while the gray matter consists of nerve cells which enable the cord to act like the brain on occasion.

210. Involuntary Action.—The human body is largely automatic and carries on many of its processes without conscious effort, in fact, over most of the functions upon which depend the health and well being of the body, the mind has no control whatever. In some cases, such as breathing and winking, we may exercise voluntary control for a short time, but ultimately the involuntary centers take up the work. By taking thought, we may increase or diminish the length of a breath, but it

would be impossible to hold our breath until we suffocated. This automatic action of the body is of immense advantage in that it relieves us of all necessity for supervision of most bodily processes, leaving the mind free to attend to the more important matters connected with mentality. The muscles under the control of the will are very different in appearance from those that are connected with involuntary action. The voluntary muscles are striped crosswise of their length while the involuntary muscles are plain. Since these latter are not attached to the bones they also lack tendons. Their movements are controlled largely by the medulla and the spinal cord, but some, especially those of the heart, have some power to contract and expand by themselves.

211. Reflex Action.—The spinal cord not only transmits nervous impulses to and from the brain, but it may act like the brain on occasion and send out impulses in response to sensations without waiting for the brain to act. Thus, when a finger is injured, we pull it out of danger before we can think about the matter. Sensations may even cause such actions in distant and different parts of the body, as when a tickling in the nose causes us to sneeze or some disagreeable sight or sound may cause fainting. Actions of this kind are called *reflex actions*. Many acts which are conscious and voluntary at the beginning may later become reflex, as in walking, skating, bicycling, and even piano playing. Such actions, though ordinarily reflex, may, however, be controlled by the will. The actions of many animals are reflex and the lower the animal in the scale of life, the less important do the higher centers of the brain become. The advantages of reflex action are that they automatically withdraw the body from injury and, like the involuntary actions, relieve the higher nerve centers of the routine work of running the body.

212. Pain and the Nerves.—Pain may be regarded as an over stimulation of the end organs. The sensations are

carried to the brain by the nerves, but the nerves themselves are insensible to such sensations. When a nerve is cut or otherwise injured, it sends a sensation such as it ordinarily sends to the brain, and this is referred back to the end organs of the nerve, though these may perhaps be a long way from the injury. Cutting the nerve which carries the sensation of sight to the eye would give the sensation of a blinding flash of light, but the nerve would feel no pain. The seat of sensation, therefore, is in the brain. If the part of a nerve which carries sensations from any part of the body to the brain be cut, all further sensation in that part of the body will be lost but it may still be capable of motion. If the part of a nerve that carries motor impulses from the brain be cut, all motion in that part of the body served by the nerve will cease. Although all sensations are felt in the brain alone, this organ is insensible to injuries to itself and may be cut without causing pain.

213. Sleep.—Like the muscles, the brain is improved by proper exercise. Hard study for a reasonable length of time is not harmful, but such study for prolonged intervals, or carried on late at night when the brain should be resting, is objectionable. After a long period of work with the brain, the cells have a shrunken appearance and a period of rest is required to restore them to their normal condition. The best rest for the brain is sleep.* An adult requires from seven to eight hours of sleep daily and growing children require somewhat more. Healthy babies sleep a large part of each day. It appears to make no difference whether one sleeps in the daytime or at night, provided the period of sleep is uninterrupted. Night, however, is usually the better time because of the greater quiet.

Practical Exercises

1. Cross your first and middle fingers and touch your nose with them. Why does it feel like two noses?

2. The "funny bone" is the name given to the place on the outside of the elbow where the nerve passes over the joint. Why does bumping this cause a tingling sensation in the fingers?

3. When a portion of a limb has been amputated, the victim often complains of pains in the lost member. Explain.

4. Why may a sharp blow on the head cause one to "see stars?"

5. What part of the nervous system guides one who walks in his sleep?

6. Why cannot one sleep standing up?

7. What part of the brain is educated in learning to play the piano?

8. When one falls asleep in his chair why does his head drop forward?

9. What part of the brain is educated by a history lesson?

10. When one's finger is burned, where is the pain?

CHAPTER XXXVI

THE NOURISHMENT OF THE BODY

214. The Need of Food.—The human body is like all other machines in that it cannot work without energy. It also requires more or less material for growth and repair (§179). The material that supplies these needs are comprised under the general name of foods. Water, oxygen, and various salts are sometimes included in the list of foods, since they are needed by the body, but they are not foods in the usual sense, and we will here confine our attention to those substances more commonly regarded as such and classed as proteins, fats, and carbohydrates, respectively (§180). These substances, as they occur in the bodies of animals and plants used for food, cannot be assimilated by the human body until they have undergone certain chemical changes which render them soluble and otherwise fit them for being absorbed. Such changes are involved in the processes of *digestion* and seem in large measure to be due to the breaking up of large molecules into smaller ones by means of certain ferments known as *enzymes*. In digestion, the enzymes act somewhat as catalyzers do in other chemical reactions and cause the digestive processes to continue without being used up themselves.

215. Value of Foods.—The carbohydrates, such as starch and sugar, and the fats, are the chief sources of food for the body. Energy may be derived from the proteins, it is true, but this is not an economical use of such foods. They are more useful in the growth and repair of the body. In order to derive enough energy from proteins, an unusual amount

would have to be eaten. As a matter of fact, we commonly use a combination of foods in our diet, if allowed a choice, which includes representatives of the three classes of foods. Combinations of this kind are bread and butter, rice and milk, pork and beans, potatoes and meat, etc. The ratio of proteins to carbohydrates in the ordinary food should be about 1 to 6. Fats, which contain more carbon in proportion to the oxygen than do carbohydrates, are useful sources of heat, and in cold countries, and in the colder months of our year, have an increased representation in our food. Certain articles of food are of much greater value in sustaining life than others. Among those of greatest value are corn, beans, peas, potatoes, and the various grains. Nuts have a high food value because of the oil and proteins they contain. Cucumbers, lettuce, spinach, and radishes contain very little food material but are valuable for the mineral salts which they contain and for giving bulk to the food. Most fruits are of little value as nourishment, though the acids, salts, and flavors found in them make them most desirable additions to our food supply. The value of a food is usually measured by the number of kilocalories it contains, a kilocalorie being defined as a thousand ordinary calories. In books on food, this unit is spoken of simply as calorie, but the kilocalorie is always meant. Those who work hard with their muscles require enough food to give about 5000 kilocalories daily. Students and those whose occupations do not require vigorous exercise need much less. High school students need about 2500 kilocalories daily.

216. The Digestive System.—In the one-celled animals, each cell, of course, secures and digests its own food, but in the more complex animals which often contain many billions of cells, the majority of which cannot come unto direct contact with the food, means must be provided for securing and transporting this food to them. Digestion is therefore carried on by certain cells for the entire body and the material

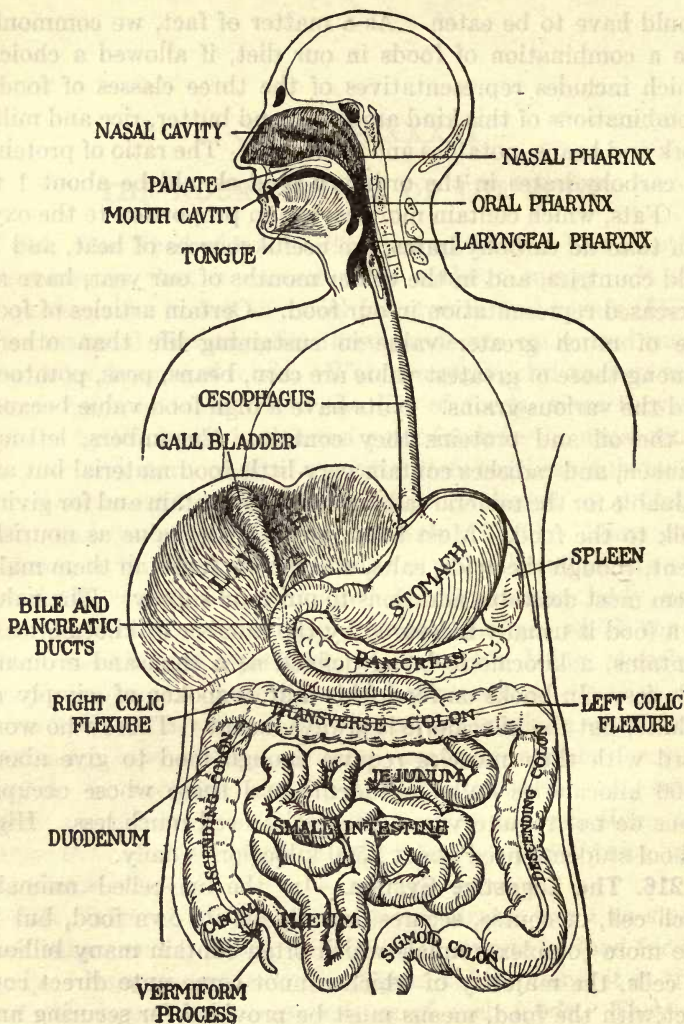


FIG. 87.—Diagram of the alimentary canal. (Morris.)

transported to the distant cells. That part of the body in which food is digested is called the *alimentary canal*. The simplest digestive system is a mere sac or stomach into which food is taken, the available material selected, and the refuse thrown out. The more complex animals, including man, have a tube extending through the body along which the food slowly moves while substances are absorbed from it. During its passage through the alimentary canal, digestive juices are poured over the food, thus rendering it soluble and capable of being absorbed. The movement of the food is caused by rhythmic contractions of the walls of the alimentary canal which forces the contents of the canal onward.

217. Structure of the Alimentary Canal.—The alimentary canal in general consists of an outer layer of muscles and connective tissue and a lining of *mucous membrane*, the latter so called because it secretes a glairy liquid, called *mucus*, which lubricates it. This membrane is much like the outer layer of the skin in structure and originates from the same tissue. There are considerable differences in the digestive organs of the different groups of animals, due in part to the kind of food they take and the kind of structures to be nourished, but all are essentially alike. In the vertebrates, there is first a *mouth* for taking the food, usually equipped with *teeth* for tearing or grinding it into small pieces, and a *tongue* for moving it about during the process of chewing. The mouth opens into the *throat* from which a tube, the *esophagus*, leads to the *stomach*, the latter largely a storage organ. Beyond the stomach is an *intestine* in which the greater part of the food is digested and from which it is absorbed. The stomach lies crosswise of the body just below the diaphragm. Ordinarily it holds about three pints but it may be distended to hold more. In man, the intestine is divided into two regions, the *small intestine* and *large intestine* respectively. The small intestine begins at the stomach on the right side of the body and owing

to its length, is much bent and coiled. It occupies most of the abdomen. The combined length of the two intestines is nearly thirty feet. The small intestine empties into the large intestine at the lower right side of the body. Near this point, a small tube two or three inches long, called the *appendix*, projects downward from the large intestine. This is often the seat of a serious inflammation called *appendicitis*. The large intestine passes upward on the right side, across the body below the stomach and downward on the left side and so on to the surface of the body. In all animals, no matter what the structure of the alimentary canal, it invariably begins in the head with the mouth.

218. Digestive Juices.—When food is taken into the mouth it is mixed with the *saliva*, a juice poured out by six glands, three on each side of the head. The glands are simply groups of cells which have the power to secrete saliva, the material for which is taken from the blood. The disease called mumps is caused by an inflammation of some of these glands. The chief use of the saliva is to moisten the food and facilitate its passage through the throat and esophagus to the stomach, though it also contains a ferment called *ptyalin* which changes some of the starch in the food to sugar. In the stomach the food comes in contact with the *gastric juice* and, by a peculiar churning movement of the stomach walls, is thoroughly mixed with it. The gastric juice contains *pepsin* and *rennin* as well as about .02 per cent. of hydrochloric acid. The acid kills many germs in the food and renders the contents of the stomach acid, thus promoting the working of the enzymes in the gastric juice which cease their activities in an alkaline medium. The pepsin changes some of the protein to more soluble forms called *peptones* and also prepares the fats for digestion by breaking up the tiny pouches in which they are found. The rennin curdles milk. As the food, now a thin, watery mixture, passes into the small intestine, the powerful

pancreatic juice is poured into it. This juice is secreted by the *pancreas*, a gland located beneath the stomach in a bend of the intestine. In animals used for food, these glands are often known as sweetbreads. The pancreatic juice has three ferments or enzymes, namely *amyllopsin* which digests starch, *trypsin* which digests proteins, and *steapsin* which emulsifies the fats by breaking them up into fatty acids and glycerine and then, by combining them with alkalis, changing them into soaps. The pancreatic juice, therefore, is the most important digestive fluid in the body. When the pancreas does not function properly, it causes the disease known as diabetes. The contents of the stomach are acid (§122, 123), but the pancreatic juice can work only in an alkaline medium. The neutralization of the food after it leaves the stomach is accomplished by the *bile*, a strongly alkaline, yellowish fluid poured into the intestine by the liver. The liver is a dark red gland located on the right side of the body below the diaphragm. On the underside of the liver is a small sac, the *gall bladder*, in which bile is stored when not needed in digestion. The small intestine also secretes a digestive juice, but it appears to be of little importance. The digestive juices are all produced by glands whose action is controlled by that part of the nervous system not subject to the will. Many of their processes are the result of reflex action. Often the sight or smell of food will cause the glands to begin their secretions. It is due to this cause that the mouth "waters" at the thought of a particularly pleasing food. Under fear, grief, or strong excitement, the glands do not always produce a sufficient amount of their secretions, and if one takes food at such times he may suffer from indigestion.

219. The Teeth.—Only the more complex animals have teeth, though all but the simplest have some means of grinding their food. Those forms which lack teeth have horny jaws, beaks, mandibles, or other organs made from thickened

portions of the skin. In fact, the teeth, though considerably harder than bone, are really hardened portions of the skin. In man there are two sets of teeth, the first set or "milk teeth" being twenty in number and the second or permanent set containing thirty-two. There are the same number of teeth in each jaw and the same number on each side of the jaw. The first set consists of four chisel-like *incisors* in front in each jaw. Back of these on each side is a single strong *canine*

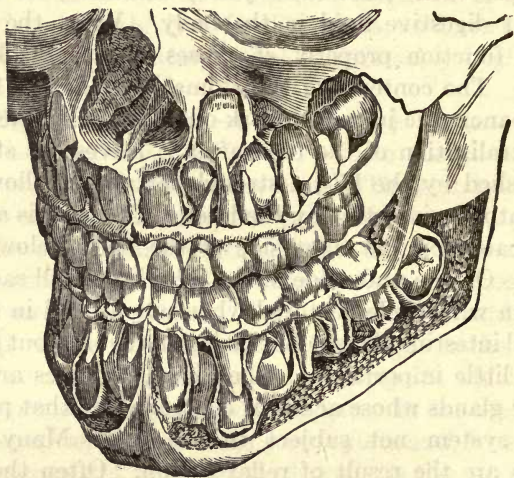


FIG. 88.—The temporary teeth. The rudiments of the permanent teeth are seen enclosed in the bones. (Gorgas.)

(cuspid) tooth and back of the canines two teeth with flattened surfaces for grinding and called *molars* in consequence. The milk teeth fall out one by one and are succeeded by stronger teeth of the same kind. In this permanent set, three larger grinding teeth or "back teeth" make their appearance further back on each side of the jaw. The last of these are sometimes called wisdom teeth. All the teeth are firmly set in the jaw and all are supplied with nerves and blood vessels which run

up through the roots to the sensitive pulp within. When, through decay, the pulp or nerve is exposed, toothache is the result. To preserve the teeth, they should be brushed at least once daily with a good stiff brush in order to remove particles of food which otherwise would cause them to decay. If the teeth are not cleaned after every meal, the best time to brush them is after the evening meal. When the teeth begin to decay, the dentist should be visited before the trouble has proceeded far enough to cause the tooth to ache. The tooth can then be treated without pain. It is a good plan to have the teeth inspected by a dentist at least twice a year in order that any beginning decay may be noticed in time.

Practical Exercises

1. How do clothes and shelter enable us to economize food?
2. Why may bad news cause us to lose our appetite?
3. Pick out the chief food constituents in the following food combinations: bread and butter, mush and milk, pork and beans, pancakes and sausage, macaroni and cheese, roast pork and apple-sauce, roast beef and mashed potatoes.
4. Chew a crust of bread for a long time and explain the sweet taste that develops.
5. Why may the sight of a person eating a lemon cause the mouth to water?
6. With a dull knife, scrape some cells from the inside of the cheek and examine with the microscope. What is their shape? Locate the nucleus.
7. Which of the milk teeth are first to appear?

8. Where do the first of the permanent teeth appear?
9. Which have the larger roots, the milk teeth or the permanent set?
10. Which of the milk teeth are first to fall out?
11. If you have lost a tooth, or have one that is decayed, locate it.
12. Why do the edges of the upper and lower incisors not meet?
13. How do you explain the Eskimo's fondness for fats?

CHAPTER XXXVII

THE TRANSPORTING SYSTEM OF THE BODY

220. The Blood.—After the food has been digested it still remains to be distributed throughout the body to the cells which need it. The office of distribution is performed by the *blood*, a watery fluid, yellowish in color, in which float a vast

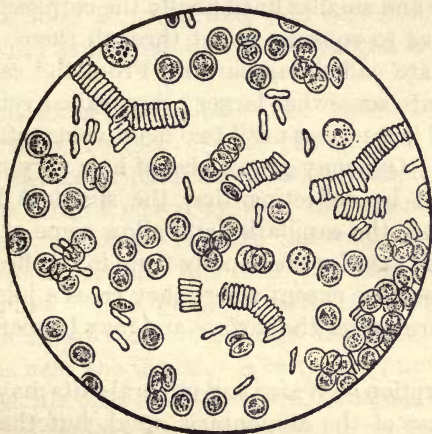


FIG. 89.—Corpuscles of blood, as seen under the microscope. Four white ones are shown. The red ones have a tendency to form rows. (*Funke and Brubaker.*)

number of very minute pinkish disks known as *red blood corpuscles*. The watery part of the blood is the *plasma*. In a cubic millimeter of blood, which is much less than a drop, there are more than five million corpuscles. These corpuscles are really cells, though they lack the customary nucleus. In

the blood of the lower animals, however, the corpuscles are nucleated. There are also to be found in the blood certain larger globular cells called *white blood corpuscles*. These are greatly outnumbered by the red corpuscles, often as much as 300 to 1. The blood is contained in a closed system of tubes called *blood vessels* and is kept in constant motion through the body by a sort of double pump, the *heart*. The tubes which carry the blood away from the heart are known as *arteries*, and those which return it to the heart are *veins*. The blood leaves the heart for its tour of the body through a single large artery, the *aorta*. This soon branches into many divisions which go to all parts of the body. As they subdivide they become smaller and smaller until finally the corpuscles, minute as they are, have to squeeze to get through them. These very small tubes are called *capillaries*. From the capillaries, the blood flows into somewhat larger tubes, called veins, and these flow into still larger ones until two main veins return the blood to the heart. One may get an idea of how very numerous the capillaries are by reflecting that the slightest break in the flesh will injure the capillaries and allow some of the blood to run out. The arteries are usually deep in the flesh and rarely come to the surface except where they cross a joint, but many of the veins are nearer the surface and may be seen through the skin.

221. Absorption.—Water and mineral salts may be absorbed from any part of the alimentary canal, but the bulk of the food is absorbed by the blood vessels of the small intestine. The walls of the intestine are abundantly supplied with blood vessels and the food passes into them by osmosis (§102). In order to pass into the blood in this way, starch has to be changed to sugar and other sugars have to be changed to grape sugar. Peptones, as such, are not found in the blood and therefore appear to undergo a second change in their passage through the mucous membrane and the walls of the

intestine. The fats are absorbed by a special set of tubes, the *lacteals*, so called because their contents have a milky appearance. The *lacteals* end in certain minute but numerous projections in the small intestine known as *villi*. It is through the walls of the villi that the emulsified fats are absorbed. The contents of the lacteals empty into the *thoracic duct*, a tube about as large as a goosequill which extends up through the thorax and empties into the general circulation under the left collar bone. The blood supply to the stomach and intestines does not return at once to the heart but flows into a larger vein, the *portal vein*, which goes to the liver. Here it again passes through a set of capillaries where much of its carbohydrate food is withdrawn and stored in the form of *glycogen*, a kind of animal starch. Glycogen is also found in the muscles.

222. Functions of the Blood.—The digested food used by the cells is carried to them by the plasma and by them built up into new tissues or oxidized to produce energy. Since the blood vessels form a closed system, the plasma, in order to reach the cells, soaks out through the walls of the capillaries into the spaces between the cells. In this condition it is known as *lymph*. The lymph is carried back to the circulation through tubes that empty into the right and left subclavian veins near the throat. The red corpuscles act as carriers between the cells and the lungs, bringing oxygen to the cells and carrying away the carbon dioxide produced in respiration. They are able to do this by means of the red coloring matter, or hæmoglobin, which they contain. This substance combines with both oxygen and carbon dioxide and absorbs whichever is more abundant. The white corpuscles act somewhat like scavengers, wandering here and there and destroying bacteria and other harmful matter wherever met. They have a sort of slow movement of their own and can pass through the walls of the capillaries in their search for employment. Here

and there along the lymphatic tubes are spongy bodies called *glands* or *nodes* in which the white corpuscles are formed. The glands also retard the passage of bacteria through them and when an adjacent part is invaded by bacteria may become swollen and tender to the touch. They are often called *kernels* when noticed under the arms or about the throat.

223. The Heart.—The heart is a hollow, pear-shaped organ composed of muscle, and is about the size of the fist. It is located in the center of the thorax between the lungs, but since the lower part is tipped somewhat to the left, the beating

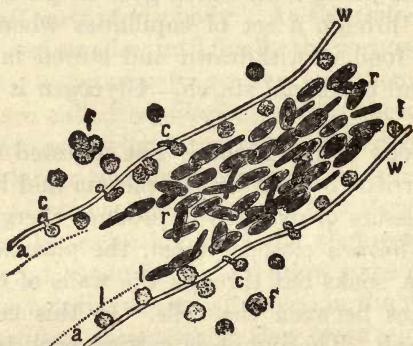


FIG. 90.—White corpuscles penetrating capillary walls. (*Landois and Stirling.*)

is felt between the fifth and sixth ribs on the left side. The heart has four chambers, two for pumping the blood and two which act as receiving chambers for it as it returns to the heart. The heart is suspended in the thoracic cavity and the blood vessels connect with it at the upper side. It beats or contracts rhythmically as long as the body is alive and gets its rest for a short period between each beat. In infancy, the heart beats about 140 times a minute, in youth the rate is from 90 to 100 and in adult life it is from 70 to 75. These pulsations may be felt in various parts of the body where the

arteries approach the surface. The normal rate at which the heart beats may be affected in various ways. It quickens with excitement and exercise and slows down during sleep or even when one lies down.

224. Circulation of the Blood.—The heart is practically two pumps in one, the right half being concerned with pumping the blood to the lungs and the left half sending it on its tour through the body. The blood returns from the body through two veins, the *venæ cavæ*, and enters the right upper chamber, the *right auricle*. From this it descends into another chamber, the *right ventricle*, which contracts much like the bulb of an atomizer and forces the blood through the lungs. From the lungs it flows back to the heart, entering the *left auricle* and flowing into the *left ventricle* whence it is again forced out through the body. At the point where the aorta leaves the heart, a set of valves prevents the blood from flow-

ing back to the heart. There are no other valves in the arteries. The walls of the arteries, being elastic, dilate as each successive heart beat adds more blood to their store and, while the heart is resting for another beat, contract and force the blood along to the capillaries. In old age and in certain diseases, the arteries lose some of their elasticity and thus fail to expand as more blood is forced into them, causing the blood

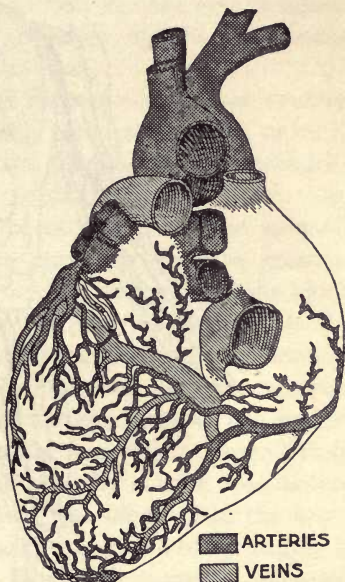


FIG. 91.—The heart. (After Bundy.)

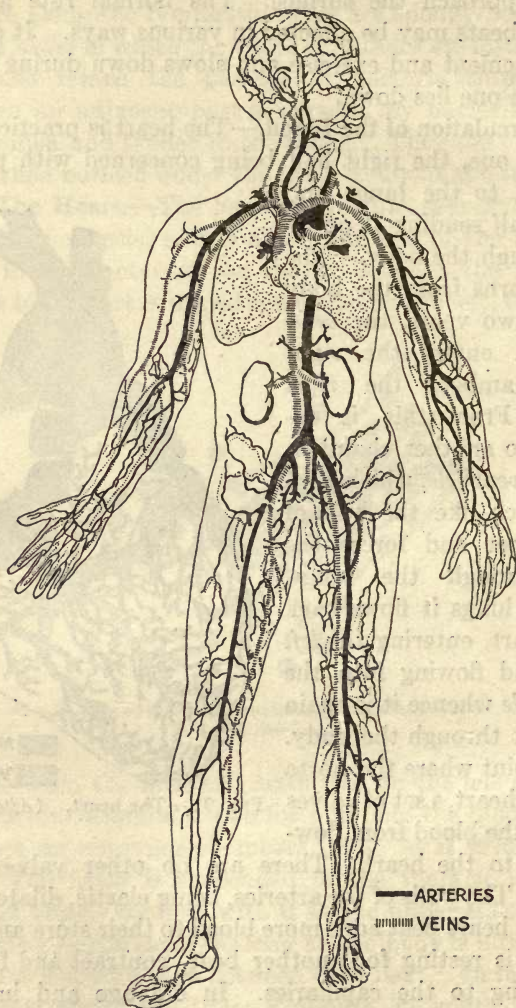


FIG. 92.—Scheme of the circulation. (After Bundy.)

pressure to increase often to a dangerous point. The immense number of capillaries into which the arteries divide distributes and lessens the pulsations of the heart and when the blood reaches the veins it shows no pulsations. The blood flows through the veins largely by reason of the pressure from the heart, though the veins have valves at frequent intervals which oblige the blood to flow in only one direction. Each movement of the muscles, therefore, aids in compressing the veins and forcing the blood onward.

225. Regulation of the Blood Stream.—Vigorous exercise increases the heart beat and more blood reaches all parts of the body in a given time, but the blood does not ordinarily flow in unvarying quantity to each tissue and organ. Instead, the flow is automatically controlled by the nervous system in such a way that the parts needing the greatest supply shall receive it. After a meal, a large part of the blood is sent to the digestive organs to provide them with the materials for work. When one is studying, a larger amount than usual is sent to the brain. In exercise, the muscles receive an increased supply. From these facts we can understand why one should not exercise vigorously immediately after a hearty meal. It also explains why a light meal before retiring may induce sleep by calling the blood from the brain to the digestive organs. The regulation of the blood supply is effected by nerves which cause the blood vessels to increase or diminish in size. In *blushing*, the capillaries are dilated and a larger amount of blood is sent to the skin. *Fear* and some other emotions cause the capillaries to contract and make the skin pale. Heat also causes the capillaries to expand and cold causes them to contract. When injuries or the attacks of bacteria cause an unusual flow of blood to any part, we speak of it as *congestion*.

226. Bleeding.—If a blood vessel is injured, the blood, owing to the pressure upon it, begins to run out. If a vein is

cut the flow will be steady, but if an artery is injured, the blood will flow in jets corresponding to the heart beats. Arterial blood may also be distinguished from venous blood by being a brighter red. Bleeding from small injuries is usually not long continued. The blood as it reaches the surface tends to thicken and form a clot. This is due to the formation of fibers of a protein called *fibrin* which entangle the red corpuscles in their meshes. Slight injuries are best cleansed with water and a mild disinfectant and wrapped with a clean cloth to prevent the entrance of dirt and bacteria. When bleeding is from an artery, the clot may be formed with difficulty, in which case it may be necessary to take up and tie the artery. In order to stop the flow of blood temporarily, the artery may be compressed by a tight bandage between the heart and the point of injury. If the flow is from a large vein, the pressure should be applied on the side of the injury farthest from the heart.

Practical Exercises

1. How many places on the body can you find where the pulse may be felt?
2. Locate the pulse at the base of the thumb on the wrist. How many times does your heart beat a minute? Make three trials.
3. Count your pulse after running a short distance or climbing one or two flights of stairs. How much has it increased?
4. After lying down for a few minutes, count your pulse. How does it compare with the count when standing?
5. Run your finger along the veins on the inside of the forearm, pressing the blood toward the wrist, and locate the valves in them.
6. Hold one hand above your head and the other down by your side while you count fifty. Explain the difference noted in the veins on the back of the hand.

7. Wind a string tightly about the finger in the direction of the finger nail and with a clean needle draw a drop of blood from near the nail. Examine with the microscope and note both red and white corpuscles.

8. Take a living frog and, spreading its toes apart, examine the web between them with the microscope. Note the corpuscles moving through the capillaries.

9. Account for the red nose of the hard drinker.

10. Why is one likely to feel sleepy after a hearty meal?

11. Is a long walk before breakfast desirable? Why?

12. Is a brisk walk before retiring desirable? Why?

13. How does vigorous exercise aid in sending fresh supplies of blood to the remote parts of the body?

14. Why does the application of a hot water bag or a mustard plaster to the skin cause it to become red?

15. Why must the blood of a mechanic circulate faster than the blood of a bookkeeper?

16. Why do we need more covering when we lie down?

17. How does tight clothing affect the circulation?

18. Why may soaking the feet in hot water relieve a headache?

19. How may rubbing the skin relieve an internal congestion?

20. How may massage affect the circulation?

CHAPTER XXXVIII

THE VENTILATING SYSTEM OF THE BODY

227. Respiration.—In the animal or plant body, energy is secured by oxidizing the food, that is, by combining the oxygen of the air with the carbon contained in the food (§103, 105). Much of the energy used in our factories is derived in essentially the same way by combining oxygen with the carbon in coal. The oxidation of the food in living things takes place in the cells, and the process is quite different from breathing which is properly only the inspiration and expiration of the air by the lungs. All living things respire, but many cannot strictly be said to breathe since they have neither lungs nor other organs for the purpose. In the simplest animals, indeed, each cell obtains the necessary oxygen for respiration from its immediate surroundings, but, in animal bodies consisting of a multitude of cells, means must be found for getting oxygen to the more distant ones whose situation prevents their obtaining it for themselves. Thus have arisen gills, trachea, lungs, and a circulatory system.

228. Organs of Breathing.—The nose, throat, trachea or windpipe, the bronchial tubes, and the lungs are the organs of breathing in man. The transfer of gases between the blood and the air goes on only in the lungs, and the other organs of breathing, therefore, serve chiefly to form a passageway between the lungs and the surface of the body. The air passes through the nose into the throat and is thereby warmed, moistened, and, to a large extent, freed from any dust it may contain. From the throat the air enters the *trachæa*. This is a short tube kept open by C-shaped rings of cartilage.

These rings may be felt from the outside of the throat just below the *larynx* or "Adam's apple." The trachea divides into two tubes or *bronchi*, one of which goes to each lung. In the lungs the bronchi are divided into many smaller tubes which finally end in the air chambers of the lungs. The trachea, bronchi and some other parts of the air passages are

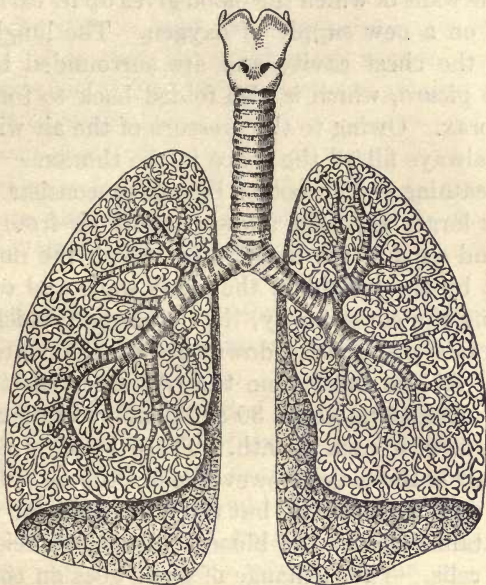


FIG. 93.—Human larynx, trachea, bronchi, and lungs; showing the ramification of the bronchi, and the division of the lungs into lobules. (Brubaker.)

lined with ciliated cells whose whip-like projections catch any dust that may be breathed in and gradually push it toward the throat, where it is swallowed. The esophagus, the tube through which food reaches the stomach, lies directly behind the trachea and all food therefore passes across the opening from the throat into the trachea. It is prevented from getting into the trachea by a spoon-shaped bridge, the *epi-*

glottis, which shuts down over the opening whenever we swallow. The *lungs* are two pinkish, spongy bodies that fill the cavity of the chest with the exception of the part occupied by the heart. They consist of an immense number of tiny sacs with walls of connective tissue lined with mucous membrane. In the walls of these sacs are a multitude of capillaries through the walls of which the blood gives up its carbon dioxide and takes on a new supply of oxygen. The lungs are hung loosely in the chest cavity and are surrounded by a membrane, the *pleura*, which is also folded back to form a lining for the thorax. Owing to the pressure of the air within them, the lungs always fill all the space in the thorax.

229. Breathing.—The act of breathing consists in making the thorax larger and thus allowing more air from outside to press in and expand the lungs, after which the impure air is forced out by the weight of the chest walls and other parts. In enlarging the chest cavity, the diaphragm which forms its floor contracts and pressed downward on the contents of the abdomen. At the same time the ribs and breast-bone rise. In ordinary breathing about 30 cubic inches of air are inhaled and exhaled with each breath. There is never a complete change of air in the lungs, however, since the air simply surges to and fro with each breath, but the rapid diffusion of the oxygen it contains enables the blood to secure sufficient for the use of the cells. The exchange of gases goes on continuously and not merely at the time the air is taken in. We are never able to expel all the air from the lungs. When we have exhaled as much air as possible, there is still left about 100 cubic inches. By taking a deep breath, the lungs may be made to hold three times this amount. There is some difference in the way men and women breathe. Men use the diaphragm as well as the ribs in breathing, but women breathe mostly by elevating the ribs, a method which the prevailing styles of dress often render necessary. The number of times one

breathes a minute depends somewhat upon circumstances. Young children may breathe as often as forty times a minute. Adults breathe from fifteen to eighteen times a minute, though when violently exercising the number of breaths a minute may rise to sixty or seventy. The muscles which control breathing are involuntary, though by taking thought we may for a time modify or even stop their action. It is impossible for one to hold his breath for more than a certain time. After that the involuntary system asserts itself. Vigorous exercise, calling for an increased amount of oxygen, causes one to breathe faster, but if the exercise is begun suddenly, we may find ourselves "out of breath," because not all the lung cells are in use. If the exercise is continued all the lung cells are soon brought into action and we find we have our "second wind" and can then exercise without becoming breathless.

230. Ventilation.—The need for an abundant supply of oxygen in the air we breathe accounts for the attention that is everywhere paid to ventilation. Nobody can work or study well in an atmosphere depleted of its oxygen, though when the supply falls short it is not noticed so quickly if the air is kept moving. Every effort should be made to have one's surroundings well ventilated. One should sleep with the window open at night, even in the coldest weather. Night air is no more harmful than day air. Many people, by the use of sleeping porches, now sleep in the open air throughout the year. Open air treatment is one of the recognized methods of treating tuberculosis or consumption. Those who are compelled to pass much of their time indoors should manage to take a brisk walk of a mile or two daily. Next in importance to ventilation is dust and dusting. A number of diseases are spread by dust, and dusty locations and occupations should be avoided whenever possible. In dusting a room a feather duster should never be used. This simply stirs up the dust

and causes it to settle in a new place. Dust should be removed with a damp cloth and the cloth thoroughly cleaned before using again.

231. The Voice.—At the top of the trachea, where it opens into the throat, is a roughly triangular arrangement of cartilage, known as the *larynx*, in which the voice is produced. In ordinary breathing, the air passes through the larynx without noise, but when we speak the edges of two flaps of tissue within the larynx are caused to approach each other and their vibrations in the current of air as it passes out of the lungs produce the *voice*. The voice is reinforced by the throat and back part of the head and modified into speech by the nose, lips, tongue, and teeth. In childhood, the voice is rather high pitched but as adult life is approached, the larynx of boys increases in size and their voices become deeper and heavier in consequence.

232. Colds.—As a result of chilling the body, the blood may be forced into the mucous membrane lining the organs of breathing and there cause an increased production of mucus with its attendant coughing and spitting. One should avoid drafts, wet feet, and insufficient clothing if one would escape colds. While an ordinary cold may only cause temporary discomfort, the inflamed membranes which accompany it are favorite breeding places of various germ diseases such as diphtheria, pneumonia, bronchitis, and tuberculosis. A few colds, especially that form known as a cold in the head, are caused by germs. One may often save himself several days of illness by avoiding the vicinity of those who are coughing, spitting, and sneezing. The best remedy for the ordinary cold is rest and an even temperature.

233. Expression of the Feelings.—The organs of breathing are also concerned in a number of actions which express our feelings or show the condition of our bodies. *Laughing* and *crying* are much alike and are both produced by short sharp

motions of the diaphragm. *Sighing* is a prolonged inspiration and expiration which appears to be intended to increase the supply of oxygen in the lungs when for any reason we have neglected to breathe deeply enough. *Yawning* is much like sighing except that the air is inspired through the mouth. It seldom occurs unless we are fatigued. *Snoring* occurs during sleep when the mouth is open and the soft palate vibrates in the divided currents of air. *Hiccough* is due to a strong spasmodic contraction of the diaphragm. In *coughing* and *sneezing* the diaphragm forcibly expels air through the mouth. The stimulation which causes coughing originates in the throat, trachea or lungs; in sneezing, it originates in the nose. Most actions of this kind are reflex.

Practical Exercises

1. How many times do you breathe a minute while sitting? Make three trials.
2. Count the number of times you breathe a minute after running a hundred feet or climbing two flights of stairs.
3. How many times does your heart beat while you are breathing once?
4. Expel as much breath as possible and measure the circumference of the thorax, passing the tape around it just beneath the arms. Then take as long a breath as possible and measure again. How many inches can you expand?
5. Get a bottle holding three or four quarts, fill it with water and invert in a large pan of water. Keeping the mouth of the bottle under water, by means of a rubber tube blow into the bottle as much air as possible with one breath. Try the experiment with a tight band around the waist. Explain the difference.
6. Speak the vowels. Do you make these sounds with the mouth open or shut?

7. What parts of the mouth do you use in pronouncing the consonants m, b and p?
8. What parts are used in pronouncing the consonants t, d and s?
9. What disadvantage is there in breathing through the mouth?
10. Why is one likely to take short breaths after a hearty meal?
11. Why is the guest chamber often unhealthful?
12. Which has the best ventilation, your church, your schoolroom, or your home?
13. Is your favorite moving picture house properly ventilated?
14. Why is it better to have clothing hang from the shoulders than from the waist?

CHAPTER XXXIX

THE COVERING OF THE BODY

234. The Skin.—The delicate and sensitive tissues of the body are everywhere covered with a protective layer called the *skin*. Not only is the entire surface of the body thus protected, but the mucous and serous membranes, the first named lining all the passages of the interior to which air has access, and the serous membrane lining the closed cavities, are essentially modified skin. Even the teeth, the hardest structures in the body, are modifications of this tissue, as are also the hair and the nails. The most important function of the skin is to protect the body from germs and mechanical injury, but it also aids in excretion and in regulating the temperature of the body. Certain of the special senses are also located in the skin.

235. Structure of the Epidermis.—There are two layers of the skin known usually as the *epidermis* or *cuticle* and the *dermis*, respectively. The epidermis is on the outside and consists of many layers of cells, flattened near the surface and more rounded deeper in the tissue. It has neither blood vessels nor nerves, and derives its materials for growth and repair from the dermis. It is constantly wearing out, as may be inferred from the rapidity with which a stain disappears from it, and is as constantly renewed by the living cells in contact with the dermis. The epidermis varies in thickness on various parts of the body, being thickest on the palms of the hands and the soles of the feet. It may become thicker elsewhere when an unusual amount of wear is brought upon it. Corns and callouses are due to the attempts of the epidermis to protect

the tissues beneath by an extra pad of its substance. When we make a blister, it is the epidermis which is pushed out by the accumulation of lymph beneath it. The deeper parts of the epidermis contain varying amounts of pigment whose relative abundance makes the difference between blondes and brunettes. Exposure to the sun or wind causes more of the pigment to develop. If this is spread in an even layer we call it *tan*; if it occurs in spots it forms *freckles*. The negro's skin is dark because of a superabundance of this pigment. Occasionally an individual is found who entirely lacks pigment. Such a person is called an *albino*.

236. The Dermis.—The dermis or true skin is made up of connective tissue and is richly supplied with blood vessels and nerves. It is loosely connected to the muscles beneath and moves smoothly over them. It is this tissue in animals that is tanned to make leather. At the point where the dermis is in contact with the epidermis, that is, on its outer surface, it is thrown up into small projections called *papillæ*. *Warts* are merely overgrown *papillæ*. The *papillæ* are set very regularly on the palms of the hands and the finger tips and this produces the fine lines or ridges with which everybody is familiar. The lower layers of the dermis are often used by the body for the storage of fat. This is especially noticeable in the region over the abdomen.

237. Outgrowths of the Skin.—With the exception of the palms of the hands and the soles of the feet, the skin is covered with fine *hairs*. These hairs are each set in a depression of the dermis and are supplied with blood vessels, nerves, and muscles. Hairs are really tubes of the same tissue that forms the epidermis. They grow from small elevations called *hair follicles*. If a hair be pulled out, another will grow in its stead provided the follicle is not injured. The hair, itself, contains neither nerves nor blood vessels though these occur in the follicles. When the skin is chilled, the muscles at the base of the hairs

attempt to make them stand erect, as the hairs of the lower animals do in cold weather. This causes the condition known as "*gooseflesh*." The difference between straight and curly hair is due to a difference in the shape of the hair itself. Curly hair is flattened; straight hair is cylindrical. When hair is artificially curled it is temporarily flattened in various ways. The *nails* are also modifications of the epidermis, designed to protect the finger tips and assist in picking up small objects. They are set in grooves of the epidermis and grow in length from the base and in thickness from the under side. Being semi-transparent they appear pink from the reflection of the blood beneath them. In the lower animals, claws, horns, beaks, feathers, tortoise-shell, and various other structures are derived from the skin.

238. Glands of the Skin.—At the base of the hairs and in other parts of the skin are certain tiny glands which pour out an oil that keeps the hairs soft and the skin flexible. These are called *sebaceous glands*. The sebaceous glands of the face sometimes become clogged with dirt and are then known as "blackheads." More noticeable are the sweat glands which give off much water when the bodily temperature rises above a certain point. Though the perspiration is noticed only when the body is warm, we perspire more or less constantly even in winter. This may be seen by touching a cold mirror or piece of metal when a thin film of moisture will appear. The sweat glands begin in the lower layers of the dermis as coiled tubes closed at the ends. The water and salt they excrete are taken from the blood like the material used by other glands. With a good lens, the openings of the sweat glands may be seen in the ridges on the finger tips. If the hands are warm, a slight pressure will cause minute drops of perspiration to appear from the openings.

239. Functions of the Perspiration.—Since the heat of the body is derived from the oxidation of the food, its production

is continuous and the surplus must be as continuously thrown off, otherwise the body would soon reach a temperature high enough to cause the death of the tissues. *Fever* is simply the excess heat which remains in the body under certain conditions. When the atmosphere is cool, most of the surplus heat is lost by radiation (§77). In winter it is necessary to put on additional clothing to prevent too rapid radiation of the heat, but in summer, when the temperature of the air is high, mere radiation is not sufficient and the nerves stimulate the sweat glands to pour out a large amount of perspiration which, evaporating, takes much heat from the body (§92). By this means the bodily temperature is kept uniform. The average temperature of the human body is 98.6° F. but the skin is usually somewhat cooler and some parts of the body, notably the liver, is several degrees warmer. Certain drugs, by affecting the nerves, may also promote the pouring out of the perspiration. Since the air taken into the lungs is warmed during its journey through the air passages, a considerable amount of heat is also lost in breathing.

240. Care of the Skin.—The skin should be washed often enough to keep it free from the dirt and germs with which it comes in contact, as well as to rid it of the secretions left behind when the perspiration evaporates. A bath at least once a week is desirable. Daily bathing, while not absolutely necessary, is valuable for its beneficial effects upon the skin. Sufficient clothing should be worn at all times to protect the body from being chilled, but an unusual amount of clothes for wear in the house in winter is likely to prove harmful. It is much better to add extra wraps when going out into the cold than to dress too warmly indoors. Nor is it desirable that the temperature of the living rooms be high in winter. A temperature of 68°F. or 70°F. is the proper one. Since the evaporation of the perspiration depends upon the amount of moisture in the air, being greatest when the humidity is low,

merely increasing the amount of moisture in the air may make the surroundings seem warmer. The relative humidity in our dwellings and school rooms should be about 50 per cent. (§94).

Practical Exercises

1. Lift the skin on the back of the hand. How thick is it?
2. How may drinking ice-water cool the body?
3. Is it desirable to take a hot bath immediately after a hearty meal? Why?
4. If one ties a string tightly about his finger, it soon becomes cold. Why?
5. Why does wet clothing make the body feel chilly (§92)?
6. Why can a fat man endure cold better than a thin one?
7. In summer why does it seem so oppressive when the air is moist (§94)?
8. Why may rubbing the skin when the body is chilled prevent one from taking cold?
9. Touch the tips of the hairs on the back of your hand. What indication does this give that the hair follicle is supplied with a nerve?
10. The finger prints of no two persons seem to be alike. Smear your thumb or finger tip with ink and make a clear finger print of your own. Compare it with that of your classmates.
11. Draw a hair between your thumb and finger nail, pressing firmly upon it, and explain the behavior of the hair when released.

CHAPTER XL

THE EXCRETION OF WASTE FROM THE BODY

241. Need for Excretion.—So long as the body is alive it needs a steady supply of food, partly to build up new tissues and to repair worn ones, and partly to supply the energy by means of which the tissues are able to work. Ultimately, through wear or oxidation, the materials of the body break down into substances that are not only useless but harmful, and these wastes are thrown out by the organs of excretion. When carbohydrates and fats are oxidized in the body, they return to the elements from which they were made—carbon dioxide and water. Most of this carbon dioxide and part of the water are given off through the lungs. These organs, in addition to their function of supplying oxygen to the body, are thus seen to be true organs of excretion. A small amount of carbon dioxide and a much greater amount of water are excreted by the skin, and this organ also excretes some salt and urea, the latter a waste from the nitrogenous part of the food. The liver is seldom thought of as an organ of excretion, though the bile, useful as it is in digestion, contains much waste matter which, poured into the small intestine, passes out of the body with the refuse from the food. The liver also builds up certain substances from the waste matters in the blood which are returned to the blood to be later excreted by the *kidneys*. These latter are the principal organs for the elimination of protein wastes from the body and also share with the skin the duty of disposing of the excess water absorbed.

242. The Kidneys.—The kidneys are two dark red, bean-shaped organs, somewhat smaller than the fist, which lie on either side of the spinal column just below the ribs. Through the many capillaries of the kidneys, all the blood of the body sooner or later passes and these organs are therefore able to select and remove the wastes it contains. The actual work

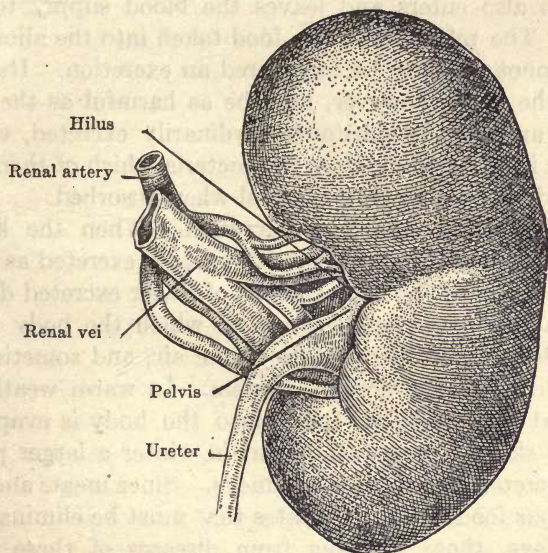


FIG. 94.—Posterior view of the right kidney. (*Morris.*)

of excretion is performed by the glandular cells of many small tubes, not unlike sweat glands in structure, which make up the bulk of the kidneys. The material excreted is not merely strained out of the blood. The action is a true excretion in which the materials are selected by the cells much as other glandular cells produce their characteristic substances. Some of the substances excreted by the kidneys, however,

appear to be formed in the liver and left for the kidneys to remove from the blood. The most abundant substance excreted by the kidneys is of course water, but with it are excreted salt, urea, and other substances which are dissolved in it. A single tube, the *ureter*, leads from each kidney to the *bladder* where the material is stored until expelled from the body. The ureter leaves the kidney from the concave side and here also enters and leaves the blood supply to these organs. The refuse from the food taken into the alimentary canal cannot properly be considered an excretion. Its retention in the body, however, may be as harmful as the retention of any of the substances ordinarily excreted, since it forms an ideal breeding place for bacteria which of themselves may produce poisons very harmful when absorbed.

243. Conditions Affecting Excretion.—When the kidneys function properly, the nitrogenous waste is excreted as fast as made in the body, but the amount of water excreted depends somewhat upon the temperature to which the body is subjected, the amount of moisture in the air, and sometimes on the condition of the nervous system. In warm weather, a large part of the water taken into the body is evaporated from the skin as perspiration, but in winter a larger proportion is excreted by way of the kidneys. Since meats and other nitrogenous foods result in wastes that must be eliminated by the kidneys, those suffering from diseases of these organs find it desirable to greatly reduce the proteins in their diet. Since the salts and other wastes excreted by the kidneys are dissolved in water, the need for drinking sufficient water to keep the kidneys flushed out is apparent.

Practical Exercises

1. Why do people suffering from kidney trouble find a warm climate desirable?

2. How may sufficient clothing relieve the kidneys of part of their work?

3. On a hot day we may drink much water without increasing the excretions from the kidneys. Why?

4. Why does vigorous exercise cause more carbon dioxide to be given off by the breath?

CHAPTER XLI

THE SPECIAL SENSES

244. Function of Sensations.—The greater part of our tissues seem designed simply for the purpose of maintaining the body as a living and healthy organism. The alimentary canal serves for the digestion of food, the blood to carry the digested food to the cells, the lungs to obtain oxygen by means of which the muscles can release the energy in the food, and the organs of excretion for the disposal of the wastes. All these functions are characteristic of living things in general and proceed automatically without the organism taking thought of the matter; indeed many of the bodily processes appear to go on as well when we are asleep as when we are awake. There is, however, another faculty developed in the body which we term *consciousness* and by means of which we are made aware of our surroundings and are thus able to enjoy existence. This faculty is located in the cerebrum which forms the upper and forward part of the brain. It communicates with the outer world through the nerves and end organs, the latter located at various places on the exterior of the body. The end organs, however, serve merely to receive and transmit sensations and have no part in the appreciation of such sensations. This latter is a function of the cerebrum alone. Some of the sensations coming to the brain have no definite sense organs for their perception and they are therefore called *general sensations*. In this group may be included, hunger, pain, thirst, fatigue, satiety and various others concerned in the upkeep of the body. Impressions from the external world, however, are all perceived by special

sense organs each designed to perceive its special kind of sensation and is incapable of reporting any other.

245. The Special Senses.—Several of the organs of special sense do not have to come in contact with what they report upon to be affected by them. By the sense of *sight*, the *eye* perceives, often at considerable distances, sizes, colors, shapes and motions and by the sense of *hearing*, the *ear* detects vibrations in other bodies. The sense of *smell* enables the *nose* to judge of the odors of substances at a distance, though in this case particles of the substance in a finely divided condition or in the gaseous form must enter the nose and come in contact with the sense organs. By the sense of *taste*, the *tongue* judges of the flavors of different substances, though this sense is not as comprehensive as we often imagine it to be, for much of what passes for taste is really due to sensations sent to the brain by the nose. To be tasted, substances have to be dissolved. The sense of *touch* is the most widely distributed of all the special senses, being located throughout the skin and in many parts of the mucous membrane as well. It is probably the sense from which all the others have been derived. The five special senses are commonly supposed to be all that the body possesses, but it can be easily shown that there is a *temperature* sense in the skin by means of which we are able to ascertain whether a thing is hotter or colder than the skin itself, and an *equilibrium*, sense in the ear which keeps the body informed of its position in space.

246. The End Organs of Special Sense.—The end organs of special sense, each responding to its appropriate stimuli, are necessarily modified for the duties they have to perform. Those which are concerned with touch and temperature are found in papillæ very much like the other papillæ of the dermis. Those which receive sensations of touch are somewhat unevenly distributed, being most numerous on the tip of the tongue, the lips, finger tips and forehead, and farthest

apart on the small of the back. The end organs which perceive differences in temperature are scarcely to be distinguished from those of touch, though they react to a different set of stimuli. The organs of smell come to the surface in the mucous membrane in the upper part of the nose, and are very similar to ordinary cells surrounding them. They are so located that they can perceive odors in the air currents as they pass into the body and thus notify us when the surrounding air is losing its purity. The sense of smell is very easily tired and, after reporting an odor for a short time, ceases to be stimulated by it. This accounts for the fact that people who work with ill-smelling materials soon cease to be annoyed by the odors. Though the sense of smell is easily fatigued, the impressions made by smells on the memory are very lasting, and the sense itself is exceedingly keen. One part of vanilla in eight million parts of air can be detected by this sense. The sense of taste is located in certain taste buds, mostly on the upper surface of the tongue. There are three forms of these taste buds; those on the back of the tongue are relatively few in number and consist of elevations each surrounded by a circular depression; those on the rest of the tongue are either thread-like bodies embedded in the other cells or are mushroom-like structures scattered here and there. These latter may be clearly seen with the unaided eye. The tip of the tongue best perceives sweets, the sides are most affected by acids, and those at the back of the tongue by bitter substances. These three classes of flavors are all that the tongue really perceives, as may be easily seen by holding the nose while testing other substances. Great heat and cold paralyze the sense of taste.

247. Sight and Hearing.—Sight and hearing, concerned with vibrations in the ether and vibrations in the air respectively, have much more complicated organs for receiving impressions than have those of the other senses. The organs

of hearing are located in a bony chamber, half the size of the finger tip, in each side of the head. This chamber is filled with a fluid into which certain delicate filaments from the nerves project, and, when the fluid is caused to vibrate, the filaments transmit sensations of sound to the brain. A narrow passage leads from the outside to this chamber and at its inner end is closed by a membrane commonly known as the *ear drum*. When vibrations fall on the ear drum, three tiny bones carry them across the short space between the ear drum and the bony chamber and cause vibrations in its contents. A tiny tube, the *eustachian tube*, leads from the throat to the inner side of each ear drum and serves to equalize the pressure of the air on the two sides of the membrane. The eyes, the only two parts of the body that are sensitive to light rays, function like a set of lenses to focus the light on an inner sensitive part, the

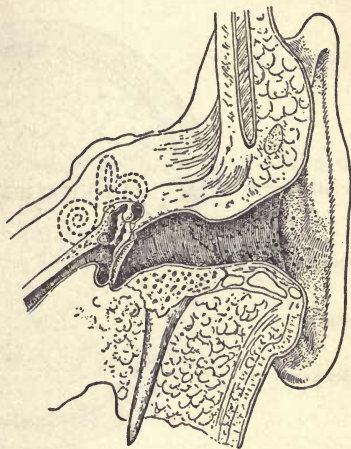


FIG. 95.—The ear.

retina, from which sensations of sight go to the brain. The interior of the eye is lined with a tissue containing pigment which absorbs such light rays as do not fall upon the retina. In the front of the eye, this pigment is visible and forms the *iris*. The dark spot or *pupil* of the eye is really an opening through the iris, and the iris itself is able to contract or expand and thus modify the amount of light admitted. Behind the iris, an organ called the *crystalline lens* aids in focussing the light rays. It is unable to move forward and back as camera lenses do, but accomplishes the same end by becoming thicker

or thinner and thus changing its curvature. The eye, being one of the most delicate parts of the body, is appropriately protected by a bony socket, eyelids and projecting eyebrows. On the upper and outer side of the eye, is a *tear gland* which supplies a watery fluid that serves to keep the eye moist and free from dust. When one is under strong emotion, or when the eye is irritated, the tear glands pour out an extra amount of fluid which gathers in drops and overflows upon

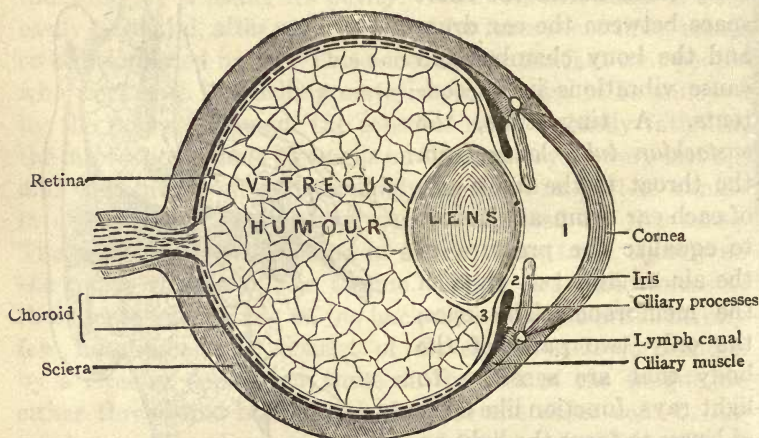


FIG. 96.—A section of the eye. (Holden.)

the cheeks. Ordinarily the surplus moisture is drained away through a tiny tube into the nose.

Practical Exercises

1. Why do we sniff when we are attempting to locate a faint odor?
2. Why does one smack his lips when carefully tasting a substance?
3. Why may a substance first taste sweet and then bitter?

4. After a spell of crying, why does the nose need attention?
5. Why may a cold in the head cause our food to lose its flavor?
6. Why has sand no taste?
7. How does holding the nose keep one from tasting nauseous medicines?
8. Wipe the tongue dry and put some sugar on it. Can you taste it? Why?
9. Of what special advantage is there in the nose being above the mouth?
10. Why may the smell of a good dinner make a hungry man's mouth water?
11. Why can you hear the ticking of a watch more distinctly when you close your teeth upon it?
12. Why may a cold cause one to hear less distinctly?
13. Can the special senses be educated?
14. Why do near sighted people without glasses bring their work so close to their eyes?
15. Why do people listening to a faint sound, open their mouths?
16. Why do people put the open hand behind their ear when trying to catch faint sounds?

17. Have a classmate touch the back of your hand, cheek, finger tips, etc., with the points of a pair of compasses. Where can you distinguish the two points when closest together?

18. Draw a thin piece of ice slowly across the back of the hand and mark with a pencil the points where cold is felt. Make the same experiment with a wire dipped in hot water. Does the same point perceive both heat and cold?

19. Why is it difficult to detect the flavor of hot food?

CHAPTER XLII

THE EFFECT OF DRUGS ON THE BODY

248. Drugs.—Although plants, or substances derived from plants, make up the bulk of our food, there are, nevertheless, many plants in the world which react in a harmful way with the protoplasm of the body. Even mustard, which is used in small quantities with the food as a condiment, when applied in larger amounts to the skin will form blisters. Contact with poison ivy or poison sumach may also cause the skin to blister, accompanied by an intolerable itching. The common nettle, if lightly touched, will sting the hand with almost the intensity of a bee sting. Fortunately there are very few plants in the United States that act as contact poisons, but there are a great many of even our common plants that will cause death if eaten. Most of these plants are harmful because of an *alkaloid* they contain, but the fact that the alkaloids strongly affect different parts of the body may be taken advantage of in medicine. In the hands of a skilful physician even the most deadly may be used in the cure of disease. The plants and plant products used in medicine are called *drugs*. In the case of most drugs, however, it is not the drugs themselves which cause the cure but rather the nervous system which is stimulated by the drugs to cause a greater activity in the cells. It is sometimes a question whether drugs are really of use in illness, and the physician is coming more and more to rely upon rest, a proper diet, and careful nursing for the recovery of his patient.

249. Use of Drugs.—Although the physician may prescribe drugs to be taken during illness, when we recover our health, we are in no need of drugs. Nevertheless, in almost every land, man has shown a disposition to make use of certain substances of this kind. Those he most favors are such as give

him a pleasurable feeling of restfulness and bodily comfort by partially stupefying the nervous system. Such drugs are called *narcotics*. Other narcotics may first act as *stimulants* and, by driving the cells of the body at a faster pace than normal, produce a feeling of ease and lightness of spirits which some people find attractive. Sooner or later, however, there comes a reaction in which the body pays for its past excesses by a feeling of dullness and depression until the person again partakes of the drug which renews the feeling of pleasurable elation. When once the use of such substances is begun, however, a craving is soon developed which can only be satisfied with new and often larger amounts of the same substance, and thus a *habit* is formed which is difficult or practically impossible to break. The commonest of the drugs containing alkaloids used by man are tea, coffee, cocoa, chocolate, opium, morphine, cocaine and tobacco. Of these, opium, morphine, and cocaine are such harmful drugs that their sale to persons other than physicians is wisely forbidden by law in most States.

250. Tea, Coffee and Other Beverages.—Tea, coffee, cocoa, and chocolate are almost universally used as beverages and in the quantities ordinarily taken seldom cause harm, though all contain alkaloids very similar in their effects upon the body. Of the four, coffee has the greatest amount of alkaloid and its use in excess often causes wakefulness, especially in those unaccustomed to its use. Cocoa and chocolate, owing to the way in which they are prepared for the table, have considerable value as food. Tea and coffee, however, are not needed by growing children and their use by them should be discouraged. Except for the sugar and cream they contain, they have no food value. In adults, however, they serve to stimulate the flow of the digestive juices and by their flavors may make the food more palatable.

251. Tobacco.—The effect of the alkaloid in tobacco is secured through smoking or chewing it, or using the powdered tobacco as snuff. Various other plants have been used for

smoking, but tobacco is the favorite wherever it can be obtained. The effects of tobacco, however, are of a more serious nature than those produced by the beverages. The alkaloid, *nicotine*, which it contains, is deadly poisonous in very small quantities. The use of tobacco diminishes the irritability of the cells and therefore produces disorder in practically all the tissues of the body. It has an especially injurious effect upon the action of the heart. It also retards the growth of new cells and its use in youth often results in a stunting of bodily growth. Its effects upon the nervous system may be seen in the trembling hand and unsteady gait of the tobacco user. In adult life, tobacco may possibly be indulged in with little harm, but even then, it is an expensive luxury which once taken up forms a habit that often inconveniences its votaries. So well known are the effects of tobacco upon children that many States forbid its sale to minors. Cigarettes appear to be no more harmful than cigars except for the fact that their small size and cheapness make them more easily accessible to the beginner. Boys who are learning to smoke should understand that many employers discriminate against the cigarette smoker and often refuse to employ him at any price. This fact, alone, should be sufficient to cause those who hope to rise in the world to abstain from tobacco. Those who use tobacco are nearly always slower mentally than those who do not use it.

252. Alcohol.—Unlike other drugs, alcohol is not derived from any particular plant, although it is a plant product. It is formed by the activities of yeast on sugary solutions whereby the sugar is broken up into carbon dioxide and alcohol. When taken into the system in small quantities, alcohol is oxidized like other foods, but in larger amounts, it acts as a narcotic whose effects are especially felt in the nerves which control the arteries and capillaries. When first taken, it may produce a sensation of warmth and pleasant lightness of feeling, but its effects are soon felt in the brain which it may stupefy to such an extent as to render its victim insensible.

Owing to the fact that it is a habit forming drug, the moderate drinker little by little becomes more intemperate until he ends a mental and physical wreck. Many States now forbid the sale within their borders of alcohol for drinking and in other States large areas have become "dry" territory. It will probably be only a short time before the drinking of alcohol will be entirely abolished. One of the most forceful reasons for the total abstinence from alcohol is the fact that practically all positions of responsibility are now barred to the user of strong drink. The boy who begins life by indulging in beer, wines, whiskey, and other liquors starts with a handicap which he can scarcely hope to overcome. He voluntarily undertakes to accept menial positions with small chance of attaining the good salaries and easy positions of his fellows who do not drink. After careful investigation, the life insurance companies have discovered that the average length of life of even the moderate drinker is less than that of the abstainer. This is partly due to the degeneration which alcohol causes in the tissues, and partly because the drinking of alcohol so lowers the vitality that the body repels disease with difficulty. Whenever an epidemic of disease spreads through a locality, it is the drinking man who first succumbs to it.

253. Patent Medicines.—The shelves of every drug store are stocked with a vast array of patent medicines which mutely testify to the widespread habit our people have of dosing themselves. The labels on the bottles usually indicate that the contents will cure a variety of diseases, though the regular physician finds it necessary to prescribe separately for each case. There may be some patent medicines that are valuable, but the majority owe their reputed curative powers to the effects of the alcohol which they contain. In several, the percentage of alcohol is higher than it is in whiskey. Money paid for patent medicines is usually wasted. It is a good rule to take no medicine of any kind except upon the advice of a physician.

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